Predation of stocked Brook Char *Salvelinus fontinalis* by Short-finned Eel *Anguilla australis* and interactions with other salmonids in Wollondibby Creek in the high country of south eastern Australia

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ABSTRACT

This study was initiated to investigate poor survival of stocked Brook Char *Salvelinus fontinalis* in Wollondibby Creek, a tributary of Lake Jindabyne in the south eastern highlands of NSW, Australia. Sampling of the creek following stocking was carried out on two separate occasions by poisoning 17.6 km, almost the entire length of the creek in 19 sections. Collection of fish was shown to be 78% effective. Five species of fish were present in the creek: *Salvelinus fontinalis, Salmo trutta, Oncorhynchus mykiss, Anguilla australis* and *Galaxias* sp. Population density in terms of numbers of fish per hectare and kilograms of fish per hectare of all species present was determined. Recovery of stocked *S. fontinalis* was low (0.38% in 1977 and 0.15% in 1979). Distribution of salmonid populations in the creek was significantly affected by physical barriers and eel predation, not cormorants as first thought. Eel predation was confirmed by the presence of salmonids in eel stomachs and extensive fin damage as a result of eel attack. Only five *S. fontinalis* in the first sampling event and one in the second sampling event had reached angling size (250 mm). It is suggested that stocking of *S. fontinalis* not be carried out in areas where *A. australis* occurs and that careful consideration be given to the location of physical barriers in the creek when stocking and the presence of native fish.

Key words: Predation, diet, *Anguilla australis, Salvelinus fontinalis, Salmo trutta, Oncorhynchus mykiss,* Short-finned Eel, Brook Char, Rainbow Trout, Brown Trout, NSW streams.

Introduction

Wollondibby Creek is located in the south eastern (SE) highlands of New South Wales (NSW), where the cool waters facilitate the survival of introduced salmonids. The creek (36°24.8'S, 148°34.4'E) around 18km in length (Appendix Photo 1), flows into Lake Jindabyne and lies between Thredbo and Lake Jindabyne. The lake was created in 1967 by damming the Snowy River, which flows to the SE corner of Australia.

The only native fish species known to occur in the Jindabyne area were the Short-finned Eel *Anguilla australis,* possibly the Marbled (or Long-finned) Eel *Anguilla reinhardtii*, the Mountain Galaxias *Galaxias olidus* (Appendix Photo 2d) and the Climbing Galaxias *Galaxias brevipinnis.* Both eels could reach the upper Snowy River area, although Jindabyne Dam presents a considerable obstacle. *Galaxias olidus* has been substantially reduced in numbers by the introduction of salmonids (Tilzey 1976).

Stocking of Wollondibby Creek and other streams along the Great Dividing Range with Rainbow Trout *Oncorhynchus mykiss* (Appendix Photo 2c) and Brown Trout *Salmo trutta* (Appendix Photo 2b), had been an ongoing practice for many years, although *S. trutta* stocking in NSW ceased around 1967 (Arentz 1967) and has recently started again in some impoundments and streams affected by drought (S. Crocker pers, comm. 2007 DPI NSW). Stocking with Atlantic Salmon *Salmo salar* into Lake Jindabyne commenced in October 1963 (Anon 1964) and later into other areas nearby. Twenty percent of the catch in Lake Jindabyne is currently *S. salar*.

The first releases of Brook Char *Salvelinus fontinalis* (Appendix Photo 2a) into the cool highland waters of NSW were made between April and June 1970 (Anon 1970) with the aim of diversifying and further supplementing angler trout catches. These fish were produced at the Gaden (Jindabyne) and Dutton (Ebor) government trout hatcheries, following a donation of 5000 ova from the Tasmanian Inland Fishery Commission in 1968. A total of 147,000 fry were released in 1970. Even though extensive stocking of *S. fontinalis* occurred in many cold water streams throughout NSW, return to the angler and fish survival was negligible according to anglers. 30,000 stocked annually into Lake Jindabyne also produced low returns and no evidence exists of their breeding and movement into Lake Jindabyne streams. Many anglers suspected that these poor returns were due to cormorant predation and some considered it was competition with other salmonids. This study was initiated in order to determine the possible reasons for low angler return and poor survival of *S. fontinalis* after stocking. The distribution and abundance of *S. fontinalis* and possible salmonid competitors and predators were examined in a highland creek in an area where they were stocked.

Materials and Methods

Fish populations in Wollondibby Creek were sampled on two occasions, April 1977 and November 1979. The creek was stocked with *S. fontinalis* in October 1976 and July 1977 and with *O. mykiss* in July 1977.

The creek was divided into seventeen sections, which were 0.37 - 1.93 km in length, to facilitate sampling and to assess movement of fish within the creek. These sections were separated and defined by physical attributes such as fence lines, large pools, creek junctions etc. Three substantial barriers were present along the creek, waterfalls in section 5 (Appendix Photo 3a) and section 10, and a weir (Appendix Photo 3b) between sections 6 and 7 (Fig. 1). In order to determine fish densities along the creek and area of water in the creek, widths were measured at 10 m intervals for 200 m in sections 3, 4 and 8 in 1977 and sections 1,3,7,9,12,13,15 and 18 in 1979 as shown in Fig. 1, 2. The mean widths determined from the samples within a section were then used and plotted against all sections in the creek to estimate mean widths in each section. This equation describes the relationship:

$$Y = -0.1371x + 3.8759, \ r^2 = 0.4562.$$

where y = mean width of the section and x = creek section number. Thus, using calculated widths of each section, population density was determined as number of fish per hectare and kilograms of fish per hectare. The depths of the creek were also determined at three points at each interval at which widths were taken using a metre rule, one at approximately 25 cm from the waters edge near each bank and one in the middle of the creek. Mean depths were then calculated for each interval, each 200 m portion sampled and for the entire creek.

On 6 October 1976, 3911 fin-clipped *S. fontinalis* (1301 dorsal fin, 1289 anal fin, 1321 left pectoral fin) were released into Wollondibby Creek. Fish averaged 10 cm in length and 10.2 g in weight. Prior to release, the fin-clipped fish were retained in a circular pond for 9 weeks. No mortalities were experienced. Equal numbers were released at two sites, A in section 3 and B in section 14 (Fig. 1).

To determine distribution, movement and abundance of *S. fontinalis* in the creek six months later, the creek was sampled in the 17 separate sections. The whole creek was poisoned using a rotenone based ichthyocide (Commercial name - Chemfish); sections 1 to 7 on 3 - 5 April 1977 and sections 8 to 17 on 27 - 29 April 1977. The rotenone diluted, dissipated and became ineffective by the time it reached the lake below section 1 and close to the end of each poisoned station. Extreme care was taken to ensure all fish below a poison station were collected by inspecting the creek for at least one km below where the poison had become ineffective. This was done to ensure eels were not picking up moribund fish hours or days later. All fish would have been collected within 4 hours of poisoning. The relatively slow flow of the creek and the effort required to carefully check the sections necessitated splitting the exercise into two periods. Three poison stations were used during each sampling period (total of six) (Fig. 1) to effectively cover the 16.1 km of creek sampled. Rotenone was effective in most sections, however Crackenback Swamp in Section 8 was difficult to effectively sample, because of the ramifying water course, heavy weed growth and high turbidity in one of the major channels running through the swamp.

All fish collected were weighed, total length measured, sexed where possible, and scale samples were taken to estimate age. At the time extensive ageing of salmonids in a Lake Eucumbene study demonstrated that ageing could be reliably estimated from scales (Tilzey 1968). Sub-samples of scales were taken to identify the age of fish in different size classes. Length frequencies and numbers and mean size of fish in each section were compared for the three salmonid species and eels, and collections of recovered hatchery fish were recorded.

To further examine survival and movement of stocked fish three months after the first sampling, a further 4000 fin-clipped one year old *S. fontinalis* were stocked in Wollondibby Creek on 7 and 8 July 1977. One thousand with their right pectoral fin removed were released in section 3, 1000 with their adipose fin removed were released in section 6, 1000 with their left pelvic fin removed were released above and below Crackenback Swamp in section 8, and 1000 with their right pelvic fin removed were released in section 12 and 14 (Fig, 2). In addition, 2000 *O. mykiss* with their right pectoral fin removed were released on 1 and 4 July 1977 of which equal numbers were released into sections 3 and 7 (Fig. 2).

The creek was again poisoned between 18 and 29 November 1979, using the same methodology as for the 1977 sampling, except the whole creek was poisoned in one session. However, in 1979 an additional two sections were added. Section 0 at the lower end of the creek, because the water level in Lake Jindabyne had dropped exposing another 300m of stream, and section 18 (1.22 km) where the creek was less well defined and in many areas ramified into swamps and some small channels totally covered by vegetation (Fig. 2). In addition, eel sampling was included in 1979, and all stomachs of eels were preserved for food analysis.

The scenarios of the two samplings were somewhat different because, in the first sampling, fish had been stocked into a stream already holding an unknown population of fish. In the second sampling most of the fish had been removed from the creek in the first sampling prior to the stocking. However, small numbers of fish may have survived the first poisoning in the very small feeder streams of the creek along its length, and some fish may have moved into the stream from the lake in the intervening period.

In order to determine the effectiveness of the stream poisoning and the proportion of the total population of fish present in the creek to those collected, two experiments were carried out. In 1977 prior to

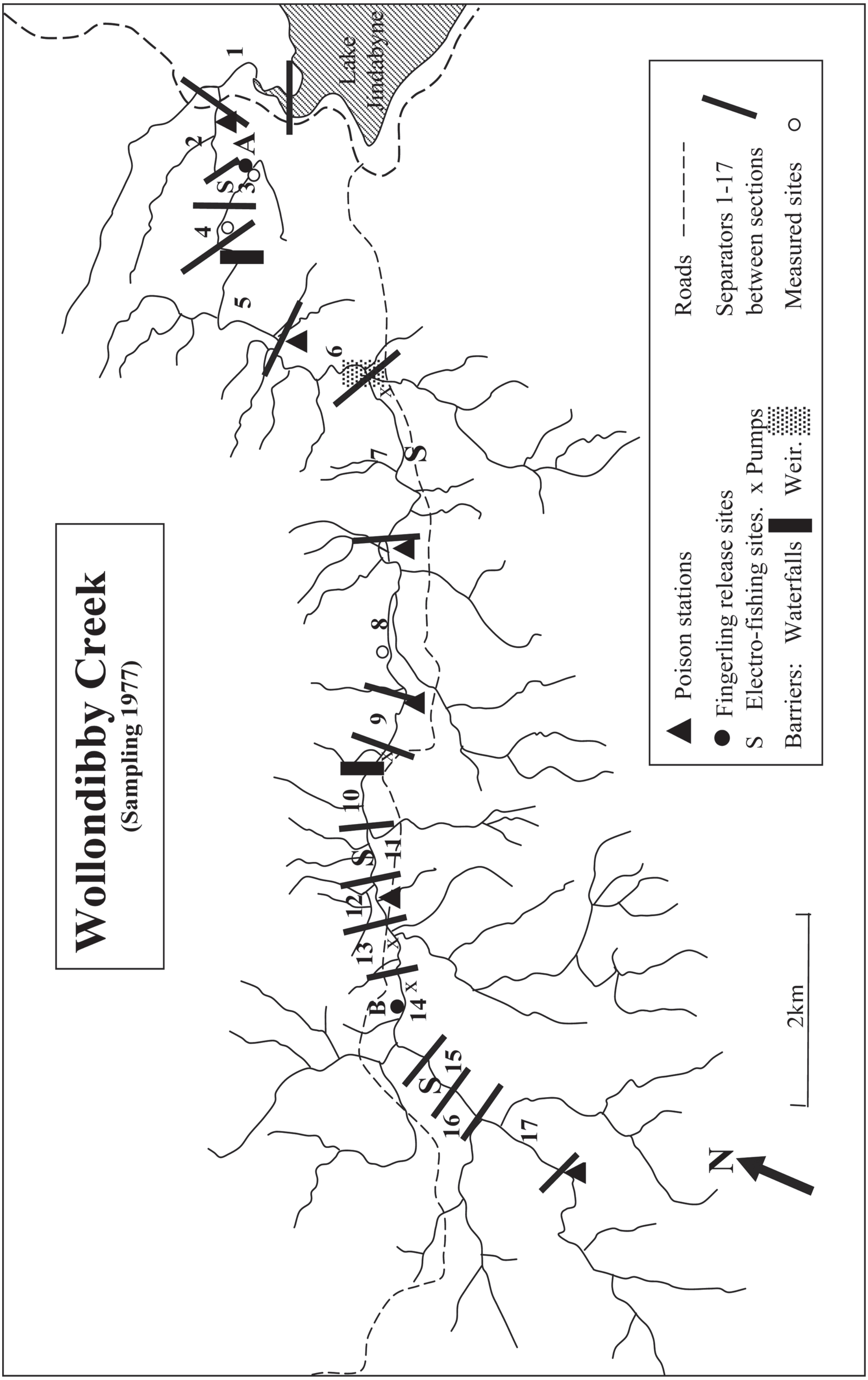

Figure 1. Wollondibby Creek showing stream sections, poison stations, experimental electro-fishing sites, release sites of *S. fontindlis* **A** and **B**, sites that were measured for width and depth, and barrier and pump sites during the 1977 sampling program.

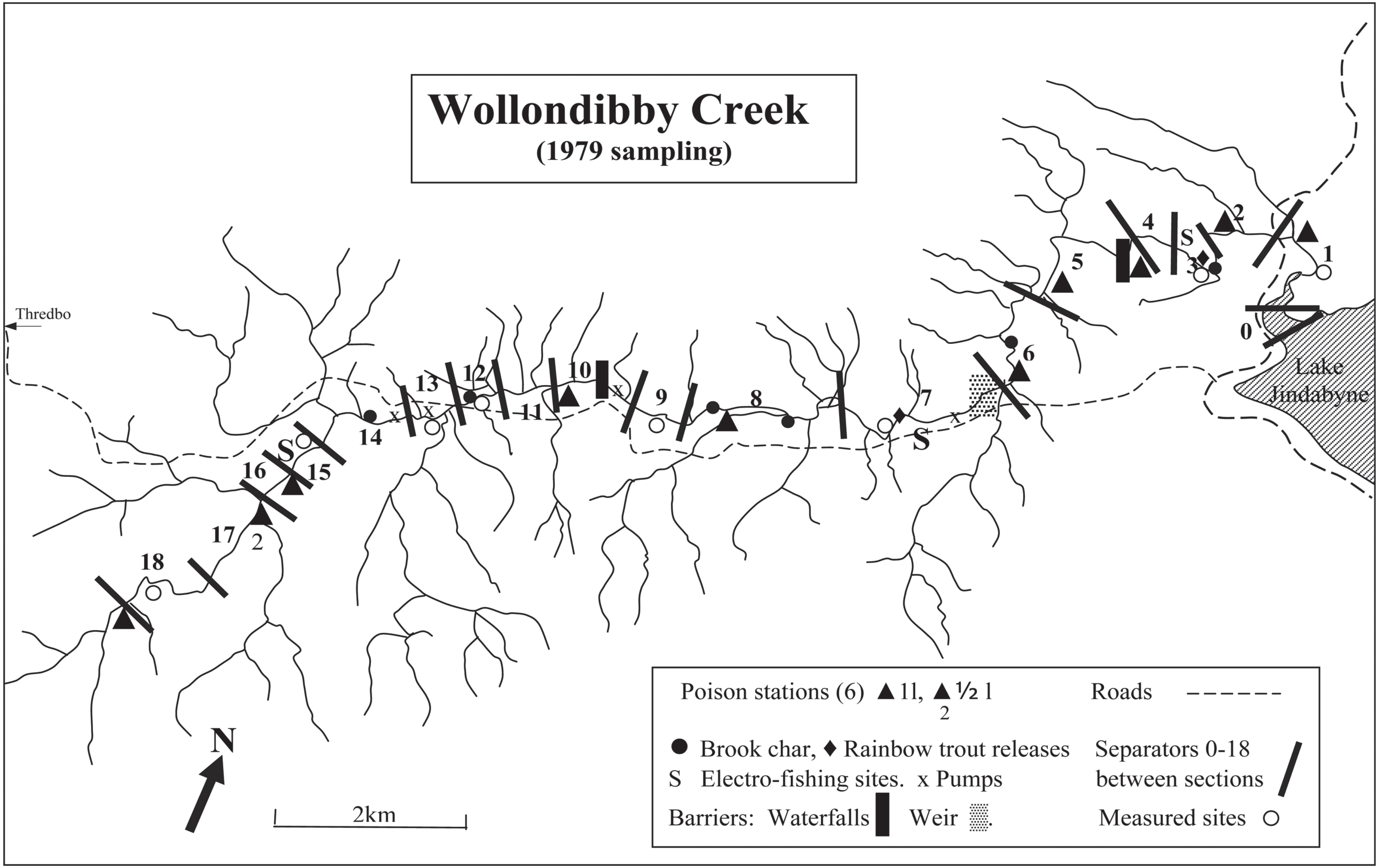

Figure 2. Wollondibby Creek showing stream sections, poison stations where ½ litre and 1 litre of poison were used, experimental electro-fishing sites, release sites of *S. fontinalis* and *O. mykiss*, sites that were measured for width and depth, and barrier and pump sites during the 1979 sampling program.

poisoning, portions of sections 7, 15 and all of section 3 and 11 were electro-fished (Fig.1). The areas electro-fished were closed off by stop nets at each end. All fish captured were marked by clipping the adipose fin and released back into each enclosure. Numbers of these marked fish collected after poisoning were counted and used to determine the percentage of fish sampled. Eels caught were not returned to the stream.

In 1979 because of malfunction of electro-fishing equipment, an experiment was carried out when the equipment was repaired when no fish were present in the creek after poisoning. Three portions of creek within section 3, 7 and 15, with stop nets at each end of each portion, were each stocked with around 20 non marked *S. trutta* (Fig. 2). The distance between stop nets was measured. Twenty four hours later the portions were then electro-fished and any *S. trutta* caught were marked by clipping a notch in the operculum and returned to the creek. Twenty four hours later the portions were poisoned with the poison station commencing approximately 50m up stream of the upper stop nets. Again numbers of marked and unmarked *S. trutta* collected were used to determine the sampling effectiveness. Stream characteristics such as heavy weed cover or high turbidity were recorded.

Results

Stream dimensions

The overall mean width of the creek based on all measurements was 2.53 m (± 1.82 SD, n =205) and based on section means was 2.69 m (SD ± 1.09, n = 11) with the mean width of Section 0 = 3.88 m and section 18 = 1.42 m. As expected, the section means declined as one ascended the stream. Lengths of each section ranged from 0.30 – 1.93 km (Tables 1, 2) and areas of each section ranged from 0.0639 – 0.5647 ha (Table 3, 4). The mean creek depth overall was 0.26 m (±0.14 SD, n = 202) with section 8 having the greatest mean depth of 0.44m. The maximum depth recorded was 1.00 m.

Estimate of effectiveness of sampling method

Sampling by poisoning was 75 - 82% effective. In 1977, 75% of the three species of salmonids caught by electro-fishing and then marked and released were recovered from the four portions of stream when the poisoning of the entire creek was complete (Table 5a). In 1979, 61 unmarked *S. trutta* were released in 3 sections of creek which should have been devoid of any fish because the entire creek had been previously poisoned. Only 17 (28%) of these were collected by electro-fishing the following day, when their operculum was notched before re-releasing (Table 5b). In the final poisoning 50 of the 61 (82%) *S. trutta* initially released were finally recovered. 13 out of the 50 recovered had notched opercula. Hence 13 out of 17 (76%) with notched opercula were recaptured in the final poisoning. Overall the two experiments indicated that collection by poisoning was 78% effective. However, these corrections have not been applied in this study because it was considered more important to present the data collected.

Distribution and abundance of fish in Wollondibby Creek

The results of the two sampling periods differ reflecting the different starting populations of wild and stocked fish in the creek, as a consequence of poisoning the whole creek in 1977, and the stocking that had occurred prior to, and after the first poisoning (Tables 1, 2).

The catch of *A. australis, S. fontinalis, O. mykiss* and *S. trutta* in each section of the creek indicates that the three barriers in the creek played a significant role in restricting upstream movement (Tables 1, 2, Fig, 3, 4). Most wild salmonid stocks from Lake Jindabyne, for example *S. trutta* (except for a few large fish during floods), do not ascend the creek past the lower barrier (Fig. 3, 4). Eels however, have the ability to climb wet surfaces, and were common above these barriers. Thus, upstream movement of stocked fish appeared to be restricted by the barriers, although some downstream movement over the barriers occurred.

Salmo trutta

Abundance of *Salmo trutta* in creek

In 1977, 273 *S. trutta* (100-530 mm total length) were collected (Table 1, Fig. 5a). Their density in sections of the creek in which they were present varied from 7.1 fish/ha in section 7 to 370.2 fish/ha in section 2 and from 1.936 kg/ha in section 6 to 16.538 kg/ha in section 2 (Table 3). Based on the total numbers and weight of fish collected, and the total area of water in the creek, there were 61.5 fish/ha and 4.507 kg/ha.

In 1979, 398 *S. trutta* (42-331 mm total length) were collected. Their density varied from 2.9 fish/ha in section 6 to 1960.8 fish/ha in section 0 and from 0.288 kg/ha in section 6 to 13.027 kg/ha in section 4. Based on the total number of fish collected and the total area of water in the creek there were 83.9 fish/ha and 1.052 kg/ha present (Table 4).

Distribution of *S. trutta*, in the creek

In both sampling periods, *S. trutta* was restricted to the lower sections of the creek. In 1977, most *S. trutta* were caught in sections 1 to 4 and part of section 5 below the lower waterfall (Fig. 3, 5b). Only 67 of the 273 *S. trutta* caught were above this waterfall in sections 5, 6 and 7, and only 3 above the weir between section 6 and 7. *S. trutta* did not penetrate above Crackenback Swamp in section 8. In 1979, only one fish of the 397 captured was above the lower waterfall in section 4 (Fig. 4, 5b, Table 2). In 1977 a majority of fish in sections 1-4 below the lower waterfall were one year old fish, probably the result of breeding in the stream by lake-run fish (Fig. 5b) and only 23 fish were of angling size above 250 mm (Fig. 5a). In 1979, 356 of the 397 fish caught were between 42 and 76 mm (0+ years), a result of spawning in the creek, while 41 were 1+ year old fish between 162 and 331mm in length (Fig. 5a). Only one fish was of angling size (Fig. 5a). In both years most of the smaller fish occurred in sections 0, 1 and 2 where ample gravel was present for spawning.

The sex ratio, for fish that could be sexed, was one male to 0.79 females in 1977 (Table 1), and one male to 1.05 females in 1979 (Table 2).

Table 1. Numbers of each sex of fish captured in each section in the 1977 sampling, together with length of sections and captures and releases of stocked fin-clipped *S. fontinalis*. (i) and (iii) are waterfalls, and (ii) is a weir, all of which are barriers to fish movement. * Predominantly swamp. ** Sandy bottom silted up with no shelter. S areas electro-fished and then fish fin-clipped and returned.

Section	Km from mouth of river (length of sections)	*O. mykiss*				*S. trutta*				*S. fontinalis*				Eel	Fin-clipped recaptured *S. fontinalis*				*S. fontinalis* Stocked 6.x.76
		♂	♀	?	Tot	♂	♀	?	Tot	♂	♀	?	Tot		♂	♀	?	Tot	
1	0-1.45 (1.45)	8	3	5	16	19	21	1	41	0	0	0	0	0	0	0	0	0	
2	1.45-2.14 (0.69)	31	18	24	73	51	41	0	92	0	0	1	1	0	0	0	0	0	
3 S	2.14-3.01 (0.87)	5	1	5	11	31	22	1	54	0	0	0	0	7	0	0	0	0	2000
4	3.01-3.38 (0.37)	2	0	4	6	5	13	1	19	0	0	0	0	0	0	0	0	0	
5(i)	3.38-5.15 (1.77)	7	1	3	11	34	18	7	59	0	0	0	0	5	0	0	0	0	
6 (ii↓)	5.15-6.28 (1.13)	18	5	3	26	3	1	0	4	0	2	0	2	0	0	2	0	2	
7 S(ii↑)	6.28-8.21 (1.93)	0	1	2	3	3	0	1	4	0	0	0	0	11	0	0	0	0	
8 *	8.21-9.98 (1.77)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
9**	9.98-10.46 (0.48)	1	0	0	1	0	0	0	0	0	0	20	20	0	0	0	0	0	
10 (iii)	10.46-11.27 (0.81)	2	1	2	5	0	0	0	0	15	9	15	39	0	3	2	1	6	
11	11.27-11.98 (0.71)	0	3	0	3	0	0	0	0	0	1	0	1	5	0	1	0	1	
12	11.98-12.40 (0.42)	0	2	0	2	0	0	0	0	0	1	0	1	0	0	1	0	1	
13	12.40-13.04 (0.64)	6	7	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	
14	13.04-14.22 (1.18)	5	1	1	7	0	0	0	0	0	2	0	2	0	0	2	0	2	1911
15S	14.22-14.59 (0.37)	1	1	1	3	0	0	0	0	0	1	0	1	1	0	1	0	1	
16	14.59-14.97 (0.38)	0	2	0	2	0	0	0	0	0	2	0	2	1	0	1	0	1	
17 *	14.97-16.10 (1.13)	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1	
TOTAL	0-16.10 (16.10)	86	46	50	182	146	116	11	273	16	18	36	70	30	4	10	1	15	3911

Table 2. Numbers of each sex of fish captured in each section in 1979, together with length of sections and captures and releases of stocked fish. R= *O. mykiss* and *S. font.*=*S. fontinalis*. Fin clips are as follows:- rc= right pectoral fin, lc= left pectoral, lp= left pelvic, rp= right pelvic, a = adipose fin and an =anal fin. (i) and (iii) are waterfalls and (ii) is a weir, all of which are barriers to fish movement. * Predominantly swamp. ** Sandy bottom silted up with no shelter. S areas electro-fished and then fish fin-clipped and returned.

Section	Kilometres from mouth of river (length of section)	*O. mykiss*				*S. trutta*				*S. fontinalis*				Eel	Fins absent			Stocked fish with fin-clips 4.vii.77	
		♂	♀	?	Tot	♂	♀	?	Tot	♂	♀	?	Tot		♂	♀	Tot	*O.mykiss*	*S.font*
0	0.30	0	3	67	70	0	0	228	228	0	0	0	0	2	0	0	0	0	0
1	0-1.45 (1.45)	1	0	0	1	1	2	0	3	0	0	0	0	1	0	0	0	0	0
2	1.45-2.14 (0.69)	4	2	1	7	8	8	29	45	0	0	0	0	9	0	0	0	0	0
3 S	2.14-3.01 (0.87)	0	0	0	0	2	1	48	51	0	0	3	3	9	0	0	0	1000 rc	1000rc
4	3.01-3.38 (0.37)	3	1	4	8	8	10	52	70	0	0	0	0	6	0	0	0	0	0
5 (i)	3.38-5.15 (1.77)	3	3	2	8	0	0	0	0	0	0	0	0	18	0	0	0	0	0
6 (ii↓)	5.15-6.28 (1.13)	16	3	0	19	1	0	0	1	0	0	0	0	17	2R lp,an	2R lp	4R	0	1000a
7 S(ii↑)	6.28-8.21 (1.93)	5	0	1	6	0	0	0	0	0	0	3	3	40	2R lp rc	0	2R	1000rc	0
8 *	8.21-9.98 (1.77)	1	0	0	1	0	0	0	0	0	0	0	0	9	0	0	0	0	1000lp
9**	9.98-10.46 (0.48)	10	0	4	14	0	0	0	0	0	1	0	1	12	0	0	0	0	0
10 (iii)	10.46-11.27 (0.81)	3	0	7	10	0	0	0	0	0	1	4	5	22	0	0	0	0	0
11	11.27-11.98 (0.71)	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	11.98-12.40 (0.42)	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	500rp
13	12.40-13.04 (0.64)	9	0	1	10	0	0	0	0	0	3	58	61	1	1R rc	0	1R	0	0
14	13.04-14.22 (1.18)	3	0	2	5	0	0	0	0	0	1	8	9	5	1R lc	0	1R	0	500rp
15S	14.22-14.59 (0.37)	0	0	2	2	0	0	0	0	0	0	0	0	10	0	0	0	0	0
16	14.59-14.97 (0.38)	1	0	0	1	0	0	0	0	0	0	0	0	11	0	0	0	0	0
17 *	14.97-16.10 (1.13)	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0
18	16.10-17.32 (1.22)	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0
TOTAL	0-17.32 +0.30 =(17.62)	60	13	91	164	20	21	357	398	-	6	76	82	190	6R	2R	8R	2000	4000

Table 3. The number and weight of fish per section, and the number and weight of fish per hectare are shown for each section from the 1977 sampling. The length and area of each section is given and the weight range of ***Anguilla australis*** is shown. MEAN 1 Based on mean of numbers and kilograms per ha only for those sections where they occur. MEAN 2 Based on mean of numbers or kilograms per ha in all 17 sections. MEAN 3 Based on total area of creek and total number or kilograms of fish in creek

Section	Creek		*O. mykiss*				*S. trutta*				*S. fontinalis*				*Total salmonids*				*A. australis*					
	Length (m)	Area (ha)	No. of fish	No. per ha	Kg	Kg per ha	No. of fish	No. per ha	Kg	Kg per ha	No. of fish	No. per ha	Kg	Kg. per ha.	No. of fish	No. per ha	Kg	Kg per ha	No. of fish	No. per ha	Kg	Kg per ha	Weight range Kg Min.	Max.
1	1450	0.5421	16	29.51	0.264	0.487	41	75.63	2.935	5.414	0	0	0	0	57	105.14	3.199	5.901	0	0	0	0	0	0
2	690	0.2485	73	293.74	1.133	4.559	92	370.20	4.110	16.538	1	4.02	0.09	0.362	166	667.96	5.333	21.459	0	0	0	0	0	0
3	870	0.3014	11	36.49	0.166	0.551	54	179.15	2.060	6.834	0	0	0	0	65	215.65	2.226	7.385	7	23.22	5.385	17.865	0.370	1.100
4	370	0.1231	6	48.73	0.111	0.902	19	154.32	0.588	4.776	0	0	0	0	25	203.06	0.699	5.678	0	0	0	0	0	0
5	1770	0.5647	11	19.48	1.143	2.024	59	104.48	7.857	13.914	0	0	0	0	70	123.96	9.000	15.938	5	8.85	4.61	8.164	0.675	1.070
6	1130	0.3450	26	75.36	3.814	11.054	4	11.59	0.668	1.936	2	5.80	0.432	1.252	32	92.75	4.914	14.243	0	0	0	0	0	0
7	1930	0.5628	3	5.33	0.384	0.682	4	7.11	1.801	3.200	0	0	0	0	7	12.44	2.185	3.882	11	19.54	8.485	15.076	0.115	1.720
8	1770	0.4919	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	480	0.1268	1	7.89	0.055	0.434	0	0	0	0	20	157.71	0.149	1.175	21	165.59	0.204	1.609	0	0	0	0	0	0
10	810	0.2029	5	24.64	0.192	0.946	0	0	0	0	39	192.22	1.198	5.904	44	216.86	1.390	6.851	0	0	0	0	0	0
11	710	0.1681	3	17.85	0.424	2.522	0	0	0	0	1	5.95	0.32	1.903	4	23.79	0.744	4.426	5	29.74	1.735	10.320	0.056	0.582
12	420	0.0937	2	21.35	0.035	0.374	0	0	0	0	1	10.67	0.204	2.177	3	32.02	0.239	2.551	0	0	0	0	0	0
13	640	0.1340	13	97.02	0.363	2.709	0	0	0	0	0	0	0	0	13	97.02	0.363	2.709	0	0	0	0	0	0
14	1180	0.2309	7	30.32	0.439	1.902	0	0	0	0	2	8.66	0.166	0.719	9	38.98	0.605	2.621	0	0	0	0	0	0
15	370	0.0673	3	44.56	0.275	4.085	0	0	0	0	1	14.85	0.075	1.114	4	59.42	0.350	5.199	1	14.85	0.94	13.964	0.940	0.940
16	380	0.0639	2	31.29	0.168	2.628	0	0	0	0	2	31.29	0.224	3.504	4	62.57	0.392	6.132	1	15.64	0.706	11.044	0.706	0.706
17	1130	0.1746	0	0	0	0	0	0	0	0	1	5.73	0.234	1.340	1	5.73	0.234	1.340	0	0	0	0	0	0
TOTAL	17,620	4.4419	182		8.968		273		20.019		70		3.092		525		32.077		30		21.861			
MEAN 1				52.24		2.391		128.93		7.516		43.69		1.945		132.68		6.745		18.64		12.739		
MEAN 2				46.09		2.109		53.09		3.095		25.70		1.144		124.88		6.348		6.58		4.496		
MEAN 3				40.97		1.996		61.46		4.507		15.76		0.696		118.19		7.222		6.75		4.922		

Table 4. The number and weight of fish per section, and the number and weight of fish per hectare are shown for each section from the 1979 sampling. The length and area of each section is given and the weight range of *Anguilla australis* is shown. N= fish not weighed. MEAN 1. Based on mean of numbers and kilograms per hectare only for those sections where fish occur. MEAN 2. Based on total area of creek and total numbers or kilograms of fish in creek.

Section	Creek		*Oncorhynchus mykiss*				*Salmo trutta*				*Salvelinus fontinalis*				Total salmonids				*Anguilla australis*					
	Length (m)	Area (ha)	No. of fish	No. per ha	Kg	Kg per ha	No. of fish	No. per ha	Kg	Kg per ha	No. of fish	No. per ha	Kg	Kg per ha	No. of fish	No. per ha	Kg	Kg per ha	No. of fish	No. per ha	Kg	Kg per ha	Weight range Kg Min.	Max.
0	300	0.1163	70	602.01	0.562	4.836	228	1960.83	0.482	4.145	0	0	0	0	298	2562.85	1.044	8.981	2	17.20	N	0	0	0
1	1450	0.5421	1	1.84	0.113	0.209	3	5.53	0.695	1.281	0	0	0	0	4	7.38	0.808	1.490	1	1.84	1.914	3.530	1.914	1.914
2	690	0.2485	7	28.17	0.572	2.302	45	181.07	1.673	6.731	0	0	0	0	52	209.24	2.245	9.032	9	36.21	9.016	36.277	0.454	1.503
3	870	0.3014	0	0	0	0	51	169.20	0.425	1.411	3	9.95	0.005	0.015	54	179.15	0.430	1.426	9	29.86	7.655	25.395	0.425	1.474
4	370	0.1231	8	64.98	0.372	3.019	69	560.44	1.604	13.027	0	0	0	0	77	625.42	1.976	16.045	6	48.73	4.650	37.765	0.340	1.134
5	1770	0.5647	8	14.17	0.766	1.356	0	0	0	0	0	0	0	0	8	14.17	0.766	1.356	18	31.88	13.410	23.747	0.113	1.503
6	1130	0.3450	19	55.07	2.594	7.518	1	2.90	0.099	0.288	0	0	0	0	20	57.97	2.693	7.806	17	49.27	12.390	35.909	0.340	1.673
7	1930	0.5628	6	10.66	0.737	1.310	0	0	0	0	3	5.33	0.009	0.016	9	15.99	0.746	1.326	40	71.07	30.364	53.949	0.199	1.673
8	1770	0.4919	1	2.03	0.043	0.086	0	0	0	0	0	0	0	0	1	2.03	0.043	0.087	9	18.30	5.571	11.325	0.142	1.304
9	480	0.1268	14	110.40	1.177	9.277	0	0	0	0	1	7.89	0.17	1.341	15	118.28	1.347	10.618	12	94.63	5.500	43.371	0.028	1.177
10	810	0.2029	10	49.29	0.582	2.869	0	0	0	0	5	24.64	0.158	0.778	15	73.93	0.740	3.647	22	108.43	7.414	36.540	0.057	1.474
11	710	0.1681	1	5.95	0.075	0.446	0	0	0	0	0	0	0	0	1	5.95	0.075	0.446	0	0	0	0	0	0
12	420	0.0937	1	10.67	0.040	0.427	0	0	0	0	0	0	0	0	1	10.67	0.040	0.427	0	0	0	0	0	0
13	640	0.1340	10	74.63	0.625	4.662	0	0	0	0	61	455.26	0.525	3.919	71	529.89	1.150	8.581	1	7.46	0.740	5.523	0.740	0.740
14	1180	0.2309	5	21.66	0.342	1.481	0	0	0	0	9	38.98	0.121	0.525	14	60.64	0.463	2.005	5	21.66	1.970	8.533	0.100	0.775
15	370	0.0673	2	29.71	0.156	2.316	0	0	0	0	0	0	0	0	2	29.71	0.156	2.316	10	148.55	3.844	57.096	0.075	0.900
16	380	0.0639	1	15.64	0.113	1.774	0	0	0	0	0	0	0	0	1	15.64	0.113	1.774	11	172.07	4.309	67.411	0.085	0.879
17	1130	0.1746	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	63.00	6.237	35.722	0.340	1.134
18	1220	0.1718	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	40.75	3.473	20.217	0.085	1.120
TOTAL	17,620	4.7299	164		8.868		397		4.978		82		0.988		643		14.833		190		118.455			
MEAN 1				68.55		2.743		480.00		4.480		90.34		1.099		265.82		4.551		56.52		29.548		
MEAN 2				34.67		1.875		83.93		1.052		17.34		0.209		135.94		3.136		40.17		25.044		

Table 5. Experiment of effectiveness of sampling in 1977 and 1979**.** Under "Amount of Creek Section ". Section numbers, distance in meters (m) and time in seconds (sec) of electro-fishing is shown.

(a). In 1977 fish were collected by electro-shocking between up and downstream stop nets and returned to area with adipose fin removed, and later recovered during poisoning.

Amount of Creek Section	*Salvelinus fontinalis*		*Oncorhynchus mykiss*		*Salmo trutta*	
	Clipped & released	Recovered	Clipped & released	Recovered	Clipped & released	Recovered
3 (870m)	-	-	4	1	24	19
7 (1000m)	-	-	-	-	1	1
11 (710m -1213sec)	1	1	2	2	-	-
15 (365m -1485sec)	2	1	2	2	-	-
TOTAL	3	2	8	5	25	20

TOTAL Salmonids clipped and released. 36. TOTAL recovered 27 (75%)

(b) In 1979 20 unmarked *S. trutta* were placed in each of three sections of creek free of fish. They were electro-fished, opercular clipped and released back into the creek on day two, and the creek was poisoned on day three. Under "Number recovered by electro-fishing", Op indicates fish caught and released with opercular notch, numbers in brackets are fish seen but not caught, + fish were seen above the stop net having passed through net, and e in brackets eels seen but not caught. Under "Number of fish, recovered by poisoning", Op indicates fish with opercular notch and e eels caught.

Amount of Creek Section	Number of *S. trutta* stocked	Number recovered by electro-fishing	Number of fish recovered by poisoning	Comments
3 (163m-1557sec)	21	5 Op (6+2)	20(inc 5 Op.)	5% weed cover, no over- hanging banks, water clear
7 (118m-869sec)	20	6 Op(3+1) (3e)	17 (inc 5 Op) 2e	20% weed cover, no over-hanging banks water murky from swamp.
15 (160m-775sec)	20	6 Op(7)	13 (inc 3 Op.)	50% weed cover, over-hanging banks in some areas nearly meeting, water clear.
Totals	61	17	50 (82%) (13 Op 76%)	

Oncorhynchus mykiss

Abundance of *O. mykiss* in the creek

In 1977, 182 *O. mykiss* (72 - 335 mm total length, maximum weight 479 g) were collected (Table 1, Fig. 6a). In sections in which they were present, their population density varied from 5.3 fish/ha in section 7 to 293.7 fish/ha in section 2, and from 0.374 kg/ha in section 12 to 11.054 kg/ha in section 6 (Table 3). Based on the total number of fish collected and the total area of water in the creek, there were 41.0 fish/ha and 1.996 kg/ha present.

In 1979, 164 *O. mykiss* (22 - 335 mm total length, maximum weight 340 g) were collected (Table 2, Fig. 6a). In sections in which they were present, their density varied from 1.8 fish/ha in section 1 to 602.0 fish/ha in section 0; and from 0.086 kg/ha in section 8 to 9.277 kg/ha in section 9. Based on the total number of fish collected and the total area of water in the creek there were 34.7 fish/ha and 1.875 kg/ha present (Table 4).

Distribution of *O. mykiss* in the creek

In 1977, *O. mykiss* were found in all sections of the creek except 8 (Crackenback Swamp), and 17 (a swampy area in the headwaters of the creek) (Fig. 3, Table 1, 3). Fifty eight percent (106) of the captured fish were found in sections 1-4 below the lower waterfall. Seventy three of these were present in Section 2 and the majority were 1+ year old (around 100mm) (Tilzey 1968) (Fig. 6a, b), presumably the result of a recent spawning of lake fish which had run up the creek to spawn.

The fish stocked in July 1977 would have been 3+ years old when sampled, and it is estimated would be over 220 mm in length (see also Tilzey 1968). Twenty of the 164 captured in 1979 were large enough to be some of these stocked fish (Fig. 6a). However, only two with right pectoral fin removed were recovered (one in section 7 where stocked, and one upstream of the stocking site, having traversed the upper barrier in section 13) (Table 2). Many recovered fish over 150 mm in length had extensive fin damage thought to be caused by eels (Fig. 7 , Table 6), which made accurate assessment of survival from fin clipping impossible. In 1979, 70 small fish around 40 mm in length were caught in section 0, a result of spawning in this area (Fig. 4; 6a, b). Fish caught upstream of the three barriers are either stocked fish, fish that have jumped the barriers or fish that avoided the 1977 poisoning. In Swamp Creek in the Eucumbene catchment where both *O. mykiss* and *S. trutta* were present Tilzey (1970) observed only *O. mykiss* jumping a significant barrier during a spate.

In 1977, 16 fish of angling size above 250 mm were caught in the whole creek (Fig. 6a) and in 1979 11 such fish were captured (Fig. 6a). The sex ratio of fish that could be sexed in 1977 was one female to 1.87 males (Table 1) and in 1979 was one female to 4.6 males (Table 2).

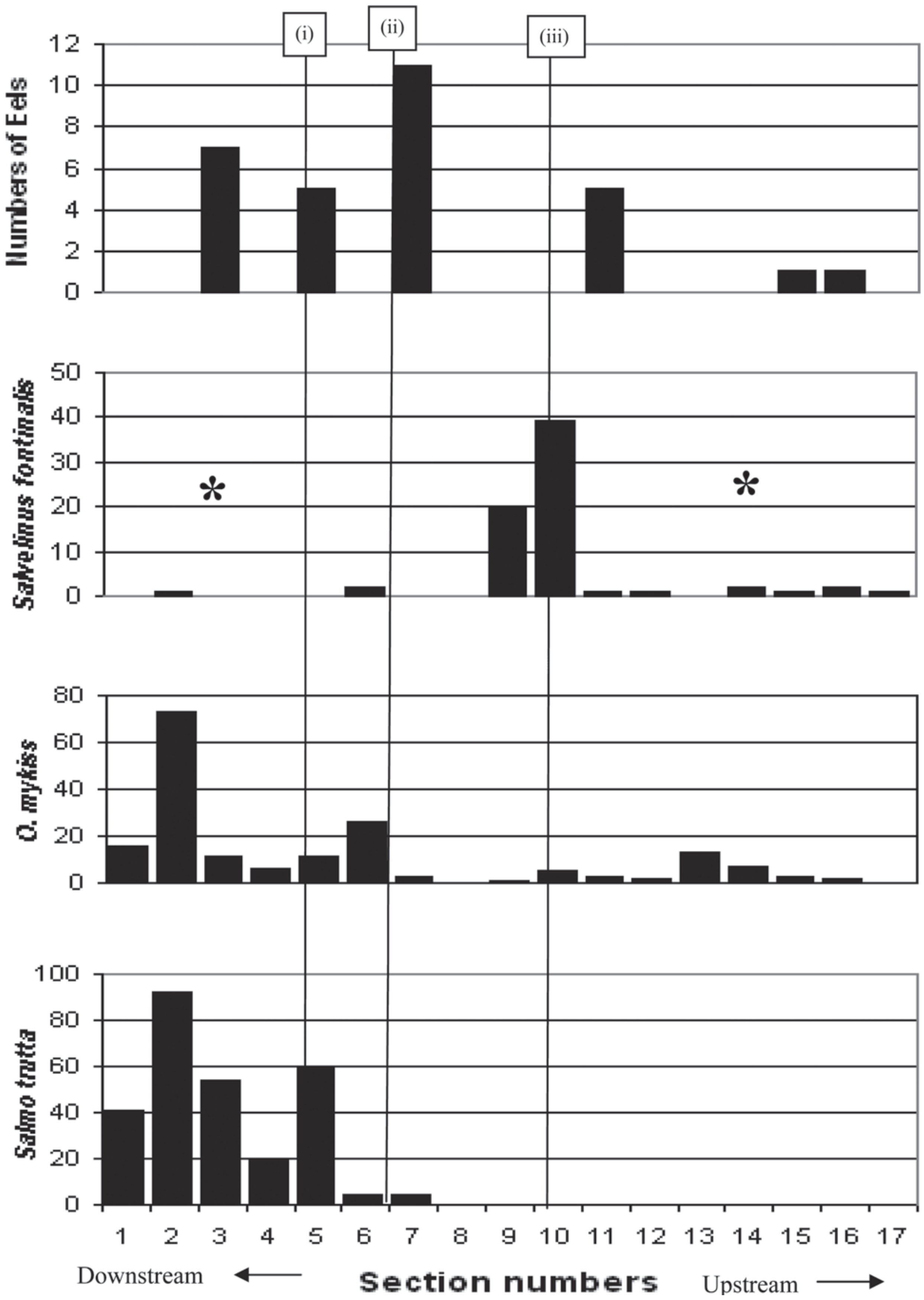

Figure 3. Numbers of Eels, *Salvelinus fontinalis, Oncorhynchus mykiss* and *Salmo trutta* collected in the 17 sections of the creek in the 1977 sampling. Lines indicate location of barriers, (i) and (iii) are waterfalls and (ii) is a weir. The asterisks indicate the location of stocking.

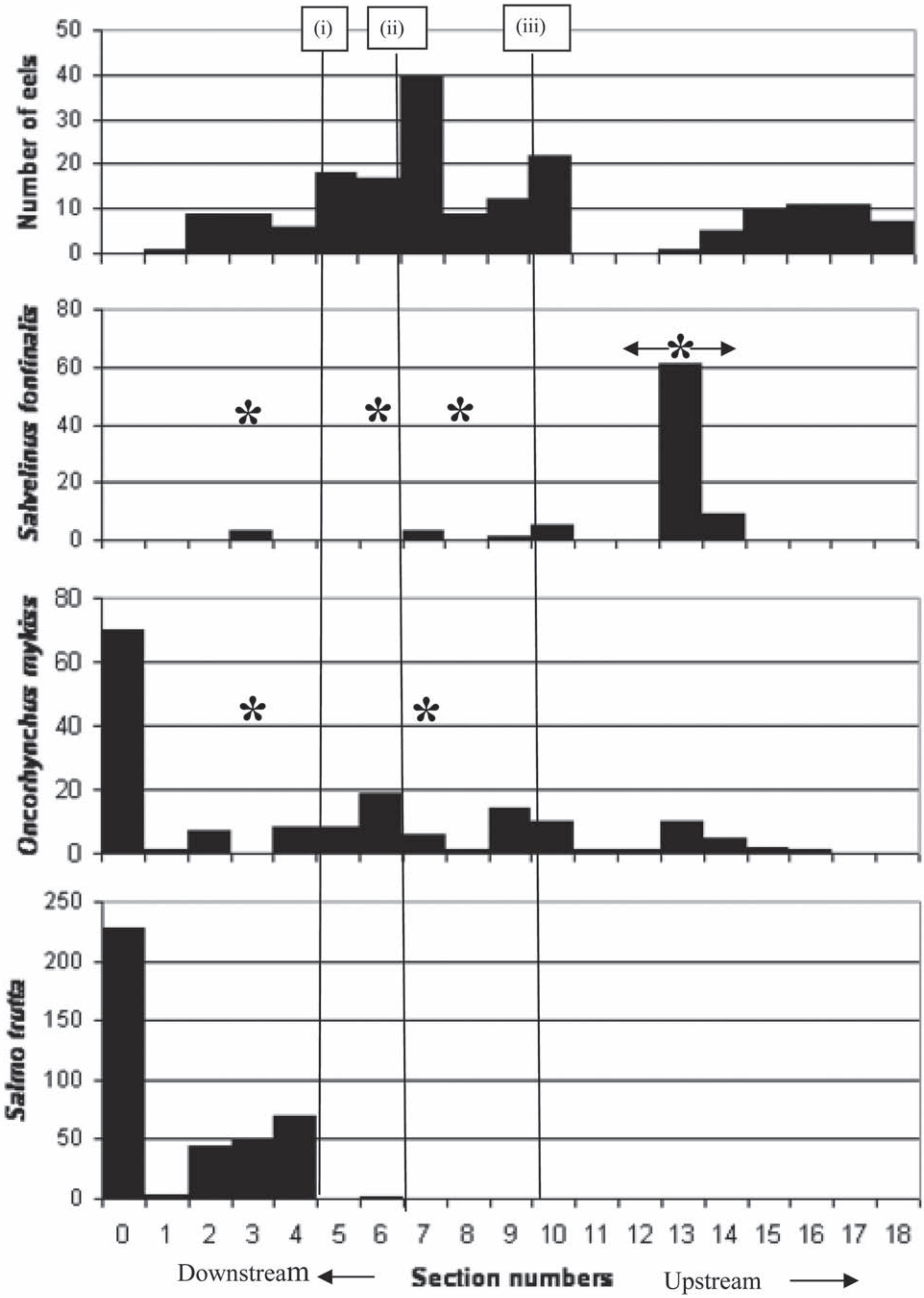

Figure 4. Numbers of Eels, *Salvelinus fontinalis, Oncorhynchus mykiss* and *Salmo trutta* collected in the 19 sections of the creek in the 1979 sampling. Lines indicate location of barriers, (i) and (iii) are waterfalls and (ii) is a weir. The asterisks indicate the location of stocking.

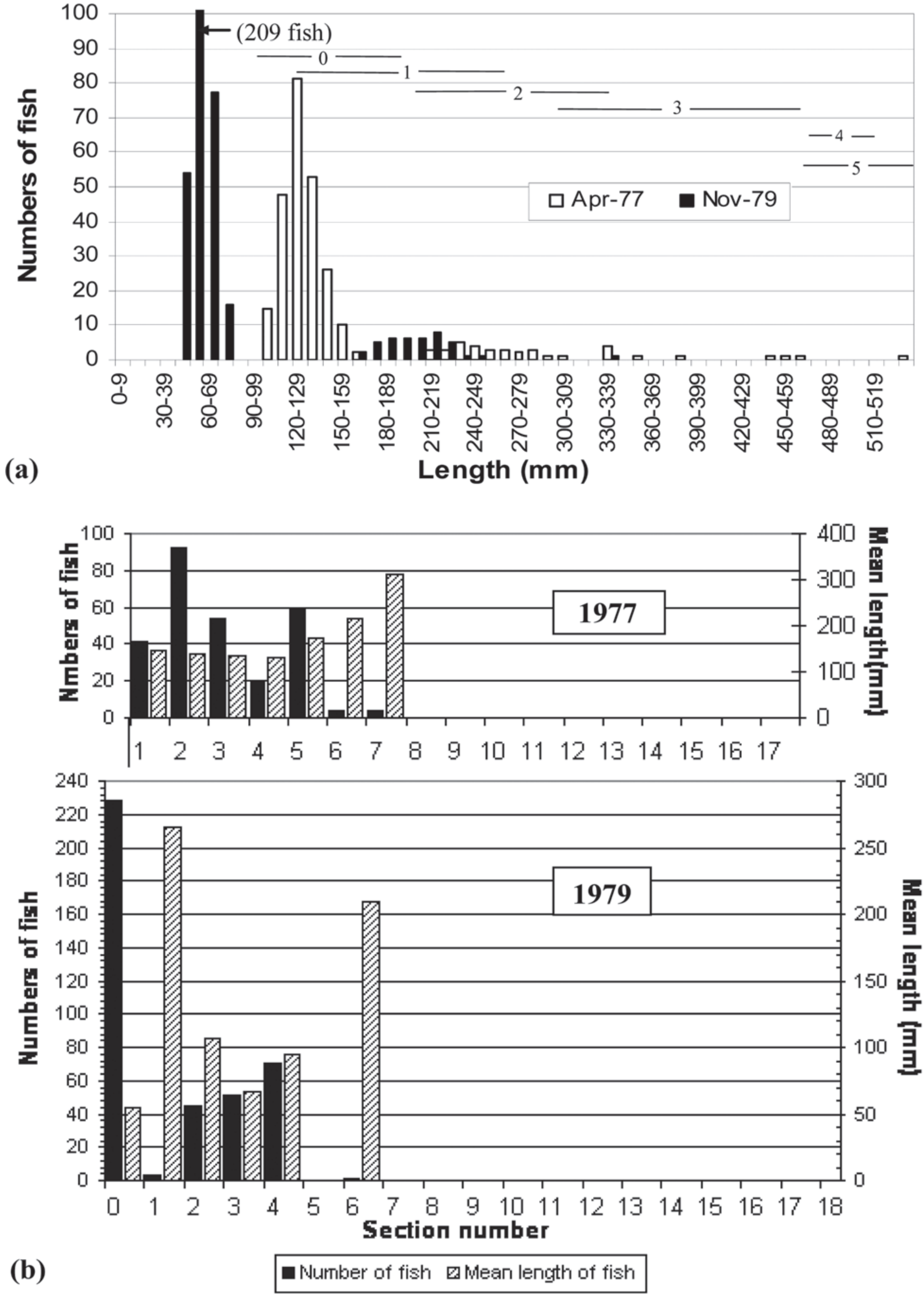

Figure 5 (a). Length frequency of *S. trutta* from all sections of creek in April 1977 (n=273) and in November 1979 (n=397). Age bars 0-5 years relate to April 1977 fish only.
(b). Number and mean length of *S. trutta* in each section of creek in 1977 and 1979.

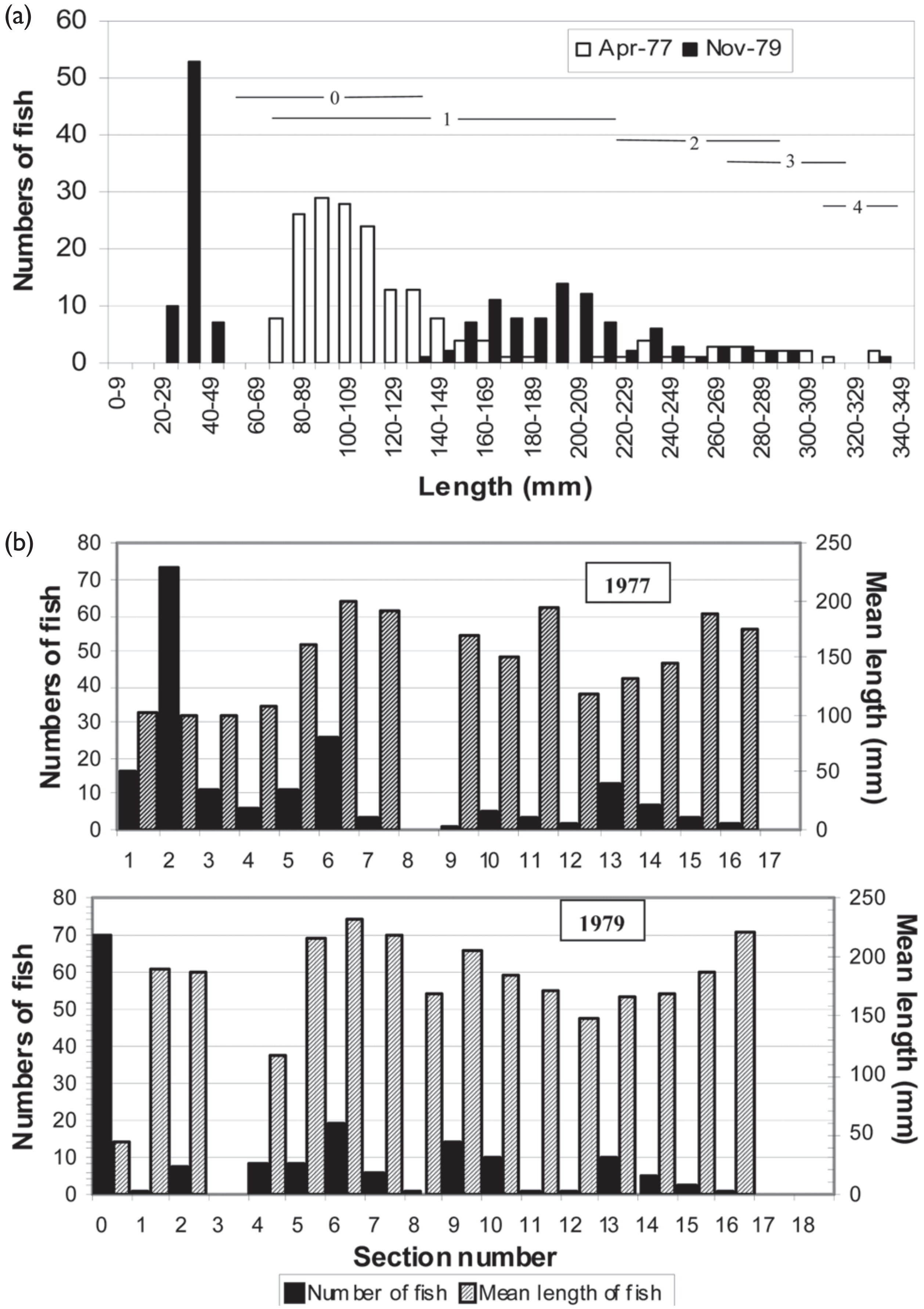

Figure 6 (a). Length frequency of *O. mykiss* from all sections of creek in April 1977 (n=182) and in November1979 (n=164). Age bars 0-4 years relate to April 1977 fish only.
(b). Number and mean length of *O. mykiss* in each section of creek in 1977 and 1979.

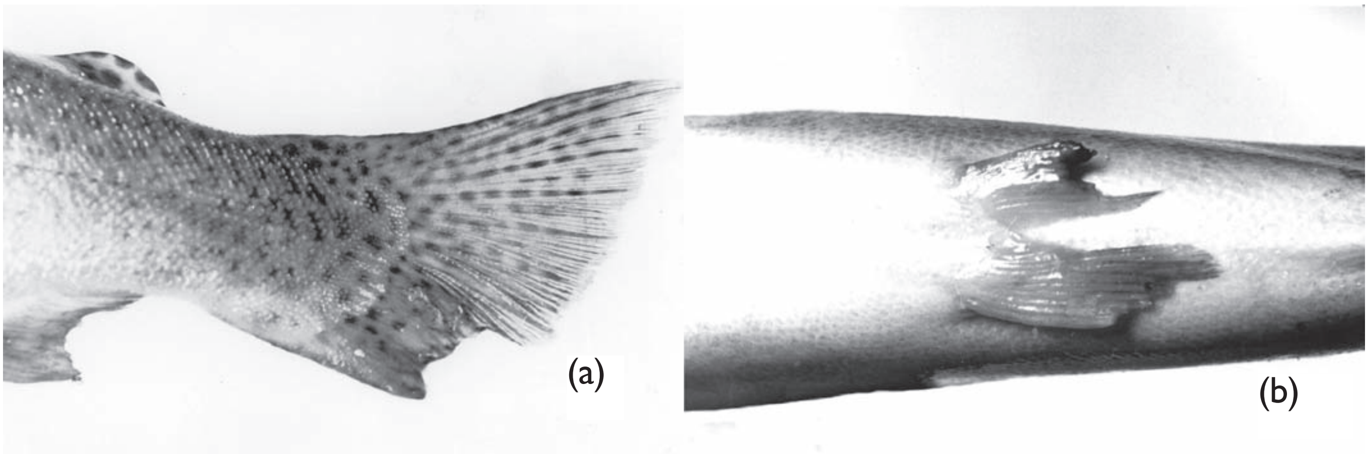

Figure 7. Damage to fins of *Oncorhynchus mykiss.* **a).** bite out of tail and anal fin. **b).** damage to pelvic fins

Table 6. Damage to salmonids showing size of fish, type of damage and fin clips recaptured in 1979 sampling. Damaged fish are generally over 150 mm total length (TL).

Section	Species	Sex	TL mm	Weight (g)	Damage (parts of fish missing)	Fin clip
2	*S. trutta*	F	230	141.8	Top of tail	
2	*S. trutta*	M	189	85.1	Top of tail	
2	*O. mykiss*	M	219	113.4	Top tail	
2	*O. mykiss*	M	165	56.7	Centre of tail	
2	*O. mykiss*	-	197	85.1	Stomach and throat	
4	*S. trutta*	-	-	-	Tail and rear body	
5	*O. mykiss*	-	250	141.8	Top of tail	
5	*O. mykiss*	-	209	85.1	Lower tail	
6	*O. mykiss*	M	297	226.8	Middle tail	
6	*O. mykiss*	F	335	340.2	Wound above ventral fin	Left pelvic
6	*O. mykiss*	F	293	226.8	Bite out of tail	Left pelvic
6	*O. mykiss*	M	234	113.4	Bite out of tail	
6	*O. mykiss*	M	201	70.9	Bite out of tail	
6	*O. mykiss*	M	273	226.8	Anal chewed	Left pelvic
6	*O. mykiss*	M	266	226.8		Anal fin
7	*O. mykiss*	M	189	85.1	Left pelvic eaten?	Left pelvic?
7	*O. mykiss*	-	249	141.8	Lower jaw and stomach	
7	*O. mykiss*	M	195	85.1	Lower tail	
7	*O. mykiss*	M	277	226.8		Right pectoral
9	*O. mykiss*	M	176	56.7	Lower tail	
9	*O. mykiss*	-	-	-	Head and intestine	
9	*O. mykiss*	M	166	28.4	Throat	
9	*O. mykiss*	M	193	56.7	Tail damaged	
10	*O. mykiss*	-	165	28.4	Tail section	
10	*O. mykiss*	-	153	28.4	Gut and lower tail	
13	*O. mykiss*	M	247	150		Right pectoral
13	*S. fontinalis*	F	207	100	Tail eaten	
14	*S. fontinalis*	F	193	100	Tail damaged	
14	*S. fontinalis*	-	55	4	Tail	
14	*O. mykiss*	M	234	140		Left pectoral

Salvelinus fontinalis

Abundance of *Salvelinus fontinalis* in the creek

In 1977, 70 *S. fontinalis* (72-282 mm total length, maximum weight 282 g) were collected (Table 1, Fig. 8a). Their density in the creek in sections which they were present varied from 4.0 fish/ha in section 2, to 192.2 fish/ha in section 10, and from 0.362 kg/ha in section 2 to 5.904 kg/ha in section 10 (Table 3). Based on the total number of fish collected and the total area of water in the creek there were 15.8 fish/ha and 0.696 kg/ha present.

In 1979, 82 *S. fontinalis* (27-255 mm total length, maximum weight 170 g) were collected (Table 2, Fig. 8a). Their density in sections in which they were present varied from 5.3 fish/ha in section 7, to 455.3 fish/ha in section 13, and from 0.015 kg/ha in section 3 to 3.919 kg/ha in section 13 (Table 4). Based on the total number of fish collected and the total area of water in the creek there were 17.3 fish/ha and 0.209 kg/ha present.

Distribution of *S. fontinalis* in the creek

Captures of *S. fontinalis* in 1977 may have resulted from natural breeding, October 1976 stocking, or from previous releases. A high number (59) of these were small fish less than 130 mm total length and were found accumulated below the waterfall barrier in sections 9 and 10 (Fig. 8a, b). These could be fish that were stocked 6 months earlier at an average total length of 100 mm and had moved a short distance downstream over the barrier. Two other fish of this size were caught below the weir in section 6, and two in section 16 and one in section 17 in a swampy area where upstream progress was difficult (Table 2; Fig.8b).

In November 1979, 75 (91.5%) of the sample were caught above the three barriers in sections 10-14 (Fig. 4, 8b), most of which were in section 13 and averaged 63 mm in length (Fig. 8a, b). Only one of the six large fish above 190 mm was caught below the upper barrier, the remaining five were all upstream of all three barriers. These six larger fish could have been 3+ years old and therefore originated from the July 1977 stocking (Fig. 8a). However, no fish could be identified as fin clipped fish from this release (Table 6).

Origin and survival of stocked *S. fontinalis*

In 1977, only 15 of the 70 *S. fontinalis* collected from the entire creek had fins missing (Table 7) and most were from fish above 185 mm in length. Thus, based on fin-clips, 21.4% of the existing population could have resulted from the October 1976 releases, meaning that the survival of the 3911 *S. fontinalis* stocked would be no more than 0.38% (Table 7). Some downstream movement of *S. fontinalis* could have occurred, some moving into Lake Jindabyne. Scars on the fish and ragged fin damage suggested that some of the fish with missing fins were not a result of fin clipping, so survival of stocked fish is likely to be even less. Fifty two of the remaining 55 unclipped, captured fish were one year olds or less (Fig. 8a), too young to be stocked fish, and are presumed to be from stream spawning in sections 9 and 10 just below the upper barrier.

Of the 1955 fin-clipped fingerlings of *S. fontinalis* released below the bottom waterfall (site A sections 1-4) in October 1976, none were recovered in the 1977 sample. Only one unclipped fish was recovered in this region. Two fin-clipped fish were collected between the lower waterfall

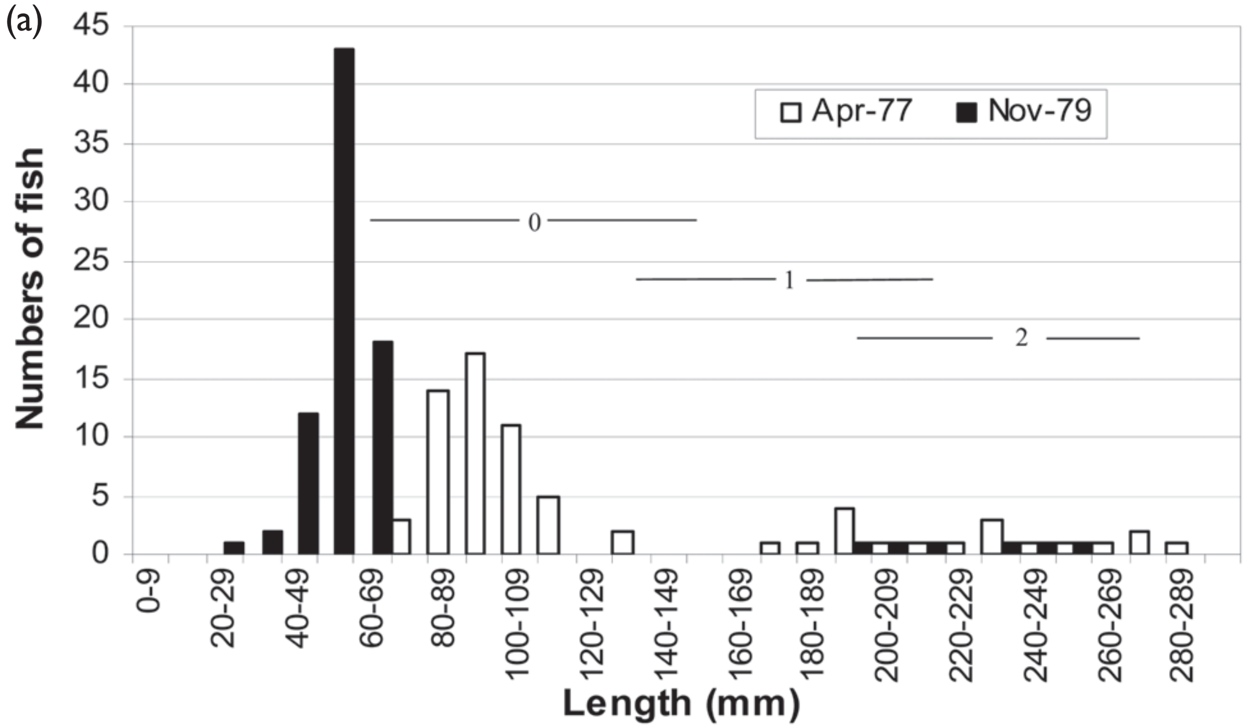

Figure 8 (a). Length frequency of *S. fontinalis* from all sections of creek in April 1977 (n=70) and November 1979 n=82. Age bars 0–2 years relate to April 1977 fish only.

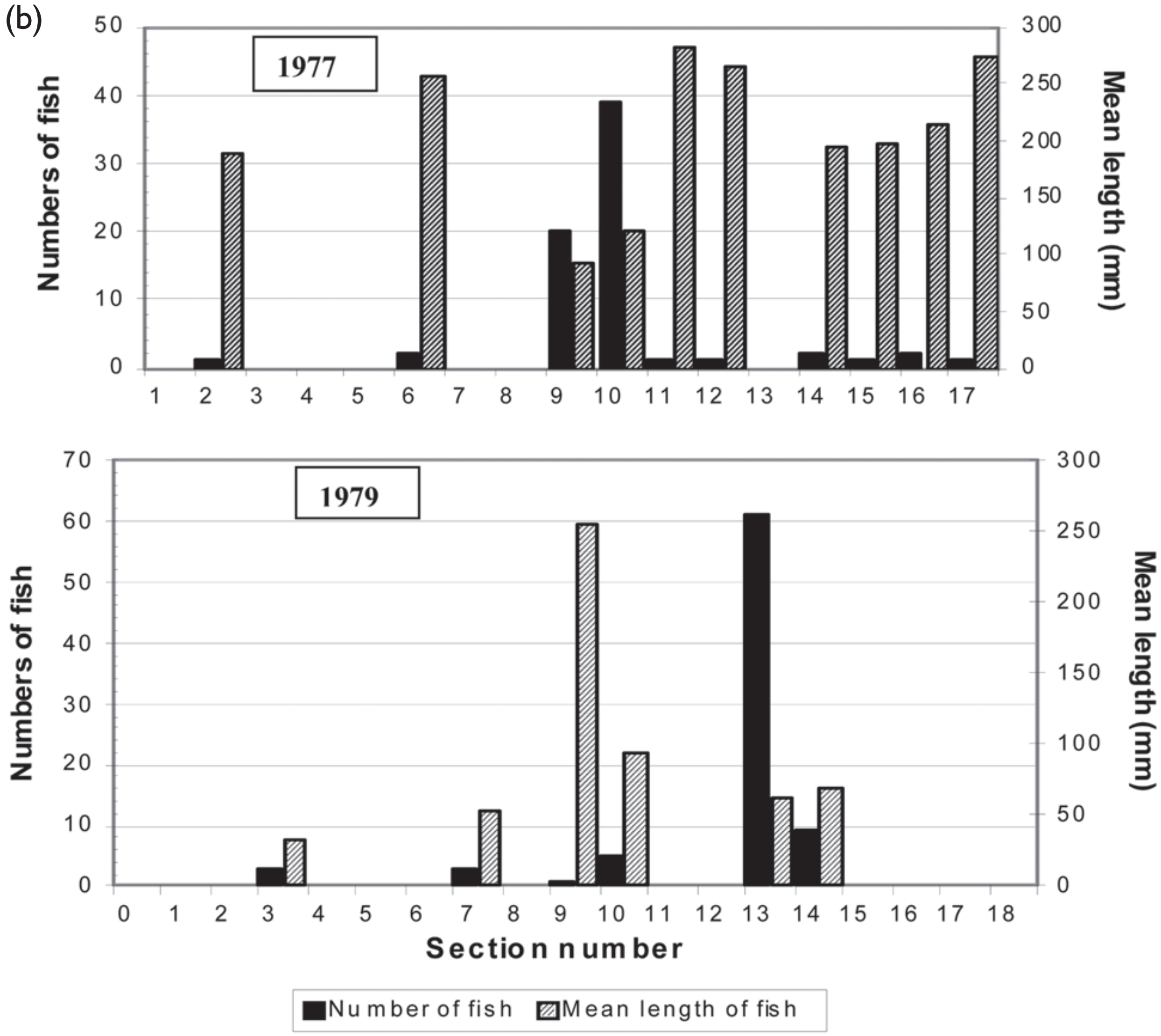

Figure 8 (b). Number and mean length of *S. fontinalis* in each section of creek in 1977 and 1979.

Table 7. Fin-clipped and wild ***S. fontinalis*** collected in Wollondibby Creek in April 1977. * Breeding occurred in the wild. Figures in parenthesis are percentage recovered.

Section	Hatchery Fish 1+ year old (3911 fin-clipped released 6.x.76)			Wild Fish		Total
	Dorsal 1301 released	Anal 1289 released	Left pectoral 1321 released	0+ year old *	1+ year old	
2	-	-	-	-	1	1
6	-	-	2	-	-	2
9	-	-	-	20	-	20
10	1	2	3	32	1	39
11	-	-	1	-	-	1
12	-	-	1	-	-	1
14	1	-	1	-	-	2
15	-	-	1	-	-	1
16	1	-	-	-	1	2
17	-	-	1	-	-	1
TOTAL	3 (0.23%)	2 (0.16%)	10 (0.75%)	52	3	70
		15 (0.38%)		55		70

and weir (sections 5 and 6), and 6 fin-clipped fish were collected between the weir and upper waterfall (sections 7-9 and lower 10) (Table 7), suggesting some downstream movement over the barrier from the stocking site at section 15 (Table 1). In the region above all the barriers (sections upper 10-17) where 1956 fin-clipped fish had been released 8 fish were collected of which 7 were fin-clipped (Fig. 8b; Table 7).

In 1979, six fish captured were large enough to be from the previous stocked fish, now 3+ years old, but none of these showed loss of any paired fins or any indication of regenerated or deformed fins as a result of fin-clipping. This suggests that either the fins had regenerated, or they were fish that had moved into the main stream from small feeder streams after the poisoning. Two of these six adults from section 13 and 14 (Fig. 8b) had lost significant parts of their caudal fin, which is not fin clipped. All six fish were females (Table 2).

Similar to that found in 1977, in 1979 76 of the 82 fish were small, below 81 mm and therefore must have resulted from breeding in the creek. It would appear that this breeding had occurred in section 13 or 14 (Table 2; Fig. 8b), above the three barriers. The few small *S. fontinalis* present downstream in sections 3 and 7 (Fig. 8b) must have been fish that had been washed downstream over these barriers.

The maximum possible survival of stocked fish based on 1979 samples collected is 6 out of 4000 (0.15%). However, as there was no indication of fin clipping on these fish the survival could be nil.

In 1977 only five and in 1979 only one (from section 9) *S. fontinalis,* from the entire creek, had reached angling size above 250mm (Fig. 8a). In 1977 the sex ratio of fish that could be sexed was 1 male to 1.13 females (Table 1), however in the 1979 sample none of the six large fish over 190 mm were males (Table 2).

Anguilla australis

Abundance of *A. australis* in creek

In 1977, 30 *A. australis* (Table 1), 330 - 890 mm in length and up to 1.720 kg in weight (Fig. 9a, Table 3) were collected, while a few others were observed to escape because the rotenone had only made them sluggish. The number of eels per hectare, in sections of the creek where present, varied from 8.9 in section 5 to 29.7 in section 11, and kilograms of eels per hectare varied from 8.164 in section 5 to 17.865 in section 3. Based on the total number of eels collected in 1977 and the total area of water in the creek there were 6.8 eels/ha and 4.922 kg/ha (Table 3).

In 1979, the number of eels using the creek had increased greatly; a total of 190 *A. australis* (Table 2), 228-982 mm in length and up to 1.914 kg in weight (Fig. 9a, Table 4) were collected**.** The number of eels per hectare, in sections of the creek where present, varied from 1.8 in section 1 to 172.1 in section 16, and kilograms of eels per hectare varied from 3.530 in section 1 to 67.411 in section 16. Based on the total number of eels collected and the total area of water in the creek there were 40.2 eels/ha and 25.044 kg/ha (Table 4).

Distribution of *Anguilla australis* in the creek

In 1977 *A. australis* were collected up to section 16 (Table 1, Fig. 3), and obviously passed the physical barriers and penetrated the entire watershed. The number of eels in each section declined as one ascended the creek, although the size of eels in each section did not vary greatly (Fig. 9b). Apart from the 7 eels in section 3, numbers were highest in sections just above the barriers (Table 1, Fig. 3). By the 1979 sampling, eels had moved into or through all sections over the two year period and they were absent only from sections 0, 11 and 12. The lack of eels or salmonids in sections 11 and 12 is surprising (Table 2, Fig. 4), but it is noted that it is immediately below the road bridge, where access and disturbance could be greatest. Again most eels were caught immediately above the three barriers, with the largest number (40) being taken in section 7 above the weir (Fig. 4, 9b).

Length frequency of *A. australis*

In 1977 only 3 of the 30 *A. australis* were below 550 mm (Fig. 9a) the smallest being 330 mm, while in 1979 there was a number of smaller eels down to 228 mm, presumably being new recruits to the watershed (Fig. 9a). The largest group of eels above 500mm was caught in 1979 (Fig.9a) and is probably from a single year class

Evidence of *Anguilla australis* attack on salmonids

In 1977, 18% of *O. mykiss*, 16% *S. fontinalis* and 1% of *S. trutta* had significant fin damage, particularly in areas where eels were prevalent. Wounds were either healed and scarred, in the process of healing, or recently inflicted (Fig. 7).

Likewise 14% *O. mykiss*, 3.6% *S. fontinalis* and 0.3% *S. trutta* were noted with fin damage in 1979 (Table 6). Seventy - five percent of *S. fontinalis* were present in a section where only one *A. australis* was present which could account for the lower percentage of damage in the 1979 sample of this species (Fig. 4). In *O. mykiss* 25.8% larger than 135mm in length were damaged, of these 14.1% had portions of their tail removed, but others were eviscerated and some had their heads removed (Table 6). The more severe attacks had occurred when the poison had taken effect, but 77% were fin attacks most of which had taken place earlier judging by the state of healing of many of them. Two of the six large *S. fontinalis* in 1979 (Fig. 8a, Table 6) and one of the small fish (55mm) had tail damage. In most circumstances, the smaller fish would have been taken whole. Out of the 41 *S. trutta* in the larger length class above 160mm in 1979 (Fig. 5a), one was extensively eaten, and only two (3.2%) had tail damage. The highest observed predation based on damage was in section 6 below the weir barrier.

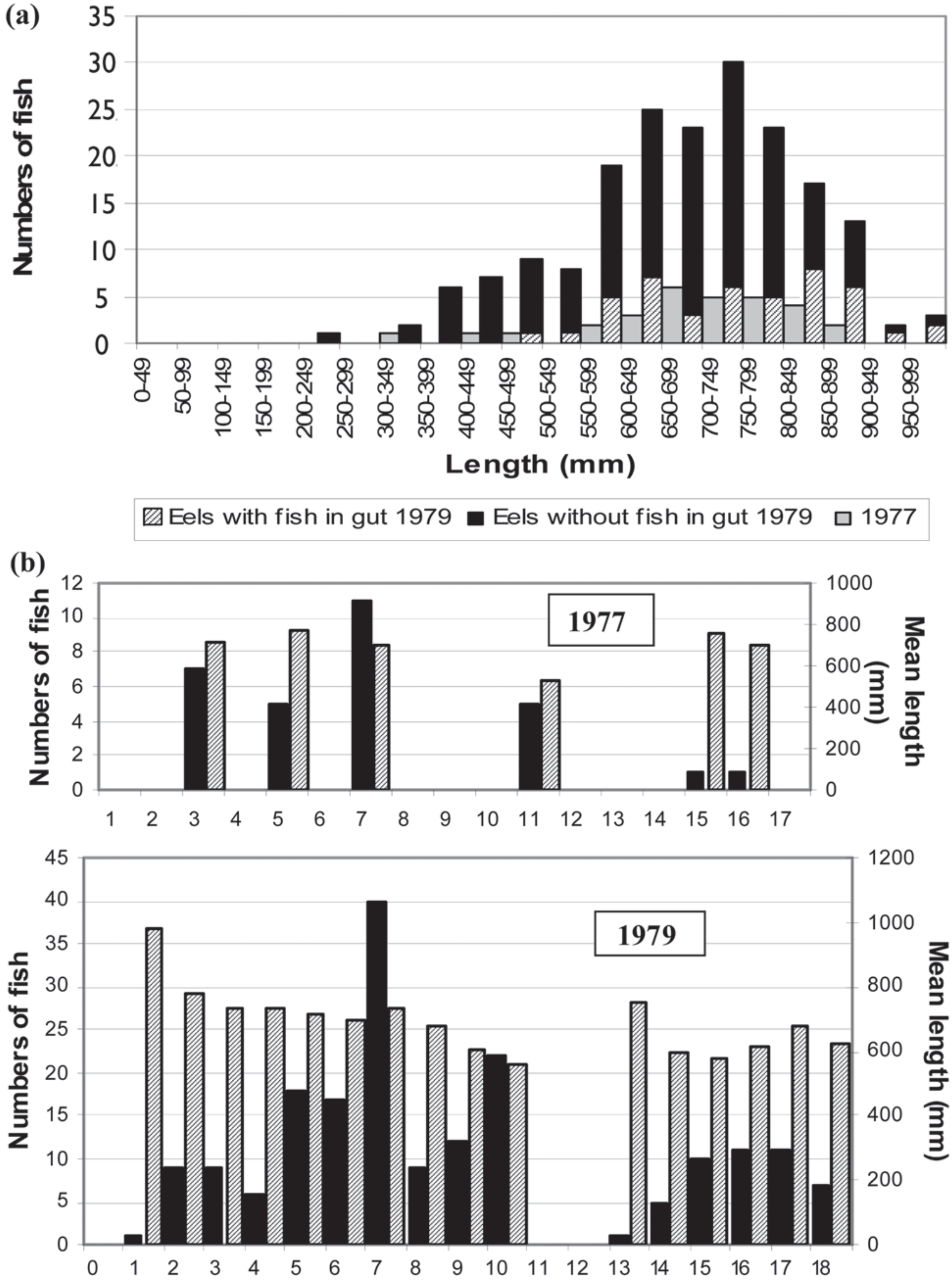

Figure 9 (a). Length frequency of *A. australis* from all sections of creek in April 1977 (n= 30 grey) and November 1979 (n=190. hatched - fish in stomach, black - no fish in stomach.).

(b). Number and mean length of *A. australis* in each section of creek in 1977 and 1979.

Inverse relationship between *A. australis* numbers and salmonid numbers

An inverse relationship existed between *A. australis* numbers and *S. fontinalis* and *O. mykiss* numbers. In 1977 most small *S. fontinalis* and *O. mykiss* were in sections where eel numbers were zero (Fig. 3, 10, Table 1). Numbers per hectare and kilograms per hectare also showed this trend (Table 3). The results from 1979 were similar (Fig. 4), although *S. trutta* in the lower creek were present whether eels were present or absent.

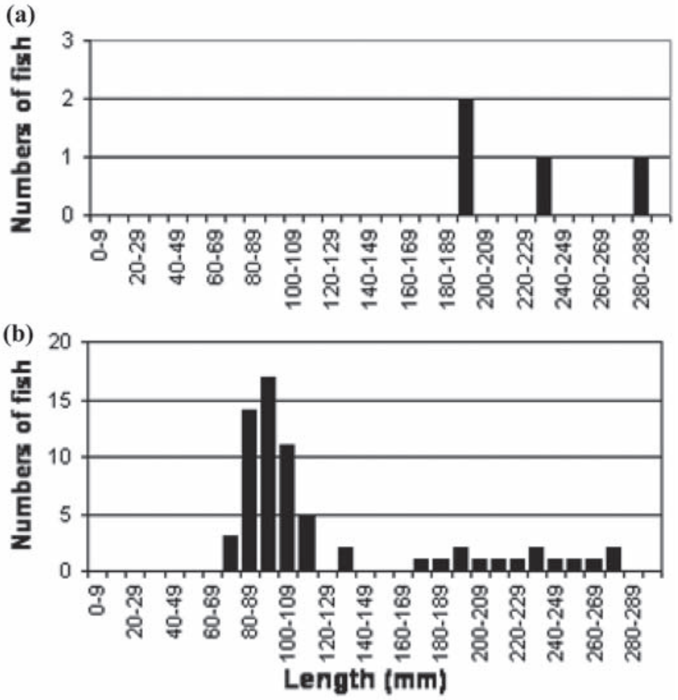

Figure 10. Length frequency of *S. fontinalis* in the 1977 sample in (a) sections of creek with eels and (b) sections of creek without eels.

Stomach contents of *Anguilla australis*

All eels caught in 1977 were over 300mm, large enough to consume small fish (Fig. 9a). To ascertain whether *A. australis* was predating on trout, the stomachs of eels were collected during the second sampling period in 1977 between 27 - 29 April, and in 1979. The stomachs of three of the seven eels examined in 1977 contained food, consisting of a variety of aquatic insects and no fish[1].

Continuous surveillance of the creek downstream of previously poisoned areas indicated the absence of any dead or dying fish in these areas. Therefore any moribund or dead fish resulting from poisoning and subsequently taken by collected eels could only have come from the poison station in which the fish were collected. This means that any fish in the stomach of eels that had been affected by poison before being taken would have to be less than 3 hours old and therefore relatively undigested, unlike a majority of eel stomach fish remains.

Examination of stomach contents in the 1979 samples confirmed that eels were predating on salmonids in the creek. Only eels above 450 mm (Fig. 9a) (92% of eels in the creek) appeared to be taking salmonids. Forty - two (22%) of the 190 *A. australis* collected had fish in their stomachs, which were most likely to be *O. mykiss* and *S. fontinalis*. The highest mean number of fish in eel stomachs (7) was recorded in section 3 (Table 8). The estimated length of fish from stomachs showed that a majority of fish were below 70 mm, although fish up to 200 mm in length were found (Fig. 11). Attacks on even larger fish are suspected judging from observed fin damage.

In addition to fish, eels were eating a wide variety of invertebrates, and the abundance of food items was often quite different in different sections of the creek (Table 8).

Galaxias brevipinnis / olidus

A single large gravid *Galaxias brevipinnis/olidus,* 18cm in length, was collected in section 7. It was close to spawning. No other galaxiids were seen or collected.

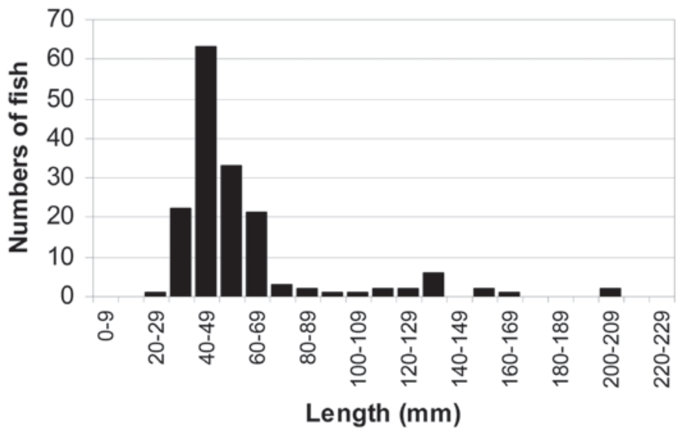

Figure 11. Length frequency of fish recovered from *A. australis* stomachs in 1979. Lengths in many cases were approximated and a majority of fish was positively identified as salmonids. (n=162).

Discussion

This study was initiated in response to anglers concerns about lack of angling success with *S. fontinalis* following stocking. Results confirmed that very few *S. fontinalis* reached angling size in the creek. In 1977 only five *S. fontinalis* in Wollondibby Creek had reached angling size (Fig. 8a) and in 1979 only one fish of the total creek population was of angling size (250 mm) (Fig. 8a). Thus return to the angler of stocked *S. fontinalis* was likely to be very low (< 0.13% found in 1977 and 0.03% found in 1979). Hobbs (1948) summarised several returns from overseas work and concluded that mean percentage returns to anglers for *S. fontinalis* were between 0.5 and 28.2%, well above those recorded in this study.

[1] Food items in the three eels sampled in 1977 were:- one with Diptera (respiratory organs), Orthoptera (grasshopper legs and terminal styles), Trichoptera (head and abdomen), cuticle, and 4 Phreatoicidae – Crustacea; the second had Orthoptera (head, abdomen, wings and legs), and Trichoptera (sand grain case); and the third had Phreatoicidae – Crustacea.

Table 8. Food items in eel stomachs within each section of Wollondibby Creek (1979). NE = Number of eels in that section with that organism in their stomach, NI = Total number of organisms in eels in that section. M= mean number of organisms in eels with this organism, (N) =nymphs, (L) = larvae, (A) = adults.

Section Number	1			2			3			4			5			6			7			8			9			10			11			12			13			14			15			16			17			18		
Number of eels	1			9			9			6			18			17			40			9			12			22			0			0			1			5			10			11			11			7		
	NE	NI	M	NE	NI	M	NE	NI	M	NE	NI	M	NE	NI	M	NE	NI	M	NE	NI	M	NE	NI	M	NE	NI	M	NE	NI	M	NE	NI	M	NE	NI	M	NE	NI	M	NE	NI	M	NE	NI	M	NE	NI	M	NE	NI	M	NE	NI	M
Fish in eels	1	4	4	9	53	6	9	62	7	5	5	1	-	-	-	3	3	1	3	3	1	1	2	2	7	17	2	3	10	3	-	-	-	-	-	-	1	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
INSECTA																																																							
Ephemeroptera(N)	1	1	4	2	8	4	5	132	26	2	53	27	12	62	5	12	258	22	28	347	12	3	17	6	2	11	6	7	51	7	-	-	-	-	-	-	-	-	-	1	1	1	2	4	2	8	33	4	8	103	13	5	16	3
Tricoptera (L)	-	-	-	3	10	3	4	60	15	2	87	44	10	29	3	14	386	28	33	1274	39	4	17	4	2	3	2	7	23	3	-	-	-	-	-	-	-	-	-	-	-	-	6	9	3	10	37	4	8	18	2	3	9	3
Plecoptera	-	-	-	-	-	-	1	1	1	1	1	1	2	5	3	5	34	7	12	47	4	1	1	1	2	2	1	5	25	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	1	1	15	15	3	14	5
Odonata (L)	-	-	-	2	2	1	-	-	-	-	-	-	4	5	1	2	2	1	2	2	1	1	5	5	-	-	-	2	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	8	3	7	22	3	3	6	2
Megaloptera (L)	-	-	-	-	-	-	1	1	1	1	1	1	11	27	2	5	13	3	-	-	-	-	-	-	1	1	1	3	5	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	4	1	-	-	-	-	-	-
Orthoptera (A)	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	1	1	1	7	10	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-
Diptera (L)	-	-	-	-	-	-	2	4	2	1	1	1	6	7	1	3	12	4	11	37	3	-	-	-	-	-	-	4	6	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	16	5	1	6	6	1	1	1
Coleoptera	-	-	-	-	-	-	1	1	1	1	2	2	3	6	2	2	2	1	3	6	2	1	1	1	-	-	-	3	3	1	-	-	-	-	-	-	-	-	-	-	-	-	2	5	3	2	7	4	2	2	1	1	4	4
Hemiptera	-	-	-	-	-	-	-	-	-	-	-	-	3	7	2	-	-	-	1	1	1	1	1	1	2	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-
Isoptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	3
Lepidoptera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Miscell Insects	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Larval case	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Egg case	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
AMPHIPODA	-	-	-	1	1	1	1	1	1	-	-	-	-	-	-	-	-	-	1	1	1	2	85	43	4	49	12	5	25	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	2	8	107	13	5	256	51
ISOPODA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	20	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	51	13	2	180	90
Yabbie	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	2	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Slug		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GASTROPODA	1	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	2	5	3
OLIGOCHAETA	-	-	-	1	1	1	3	7	2	1	2	2	-	-	-	6	9	2	15	292	19	-	-	-	1	4	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	50	50	-	-	-	-	-	-
Frog	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-
Weed	-	-	-	-	-	-	2	-	-	-	-	-	2	-	-	-	-	-	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	-	-	-	-	-
detritus	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	-	-	3	-	-	-	-	-	1	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-
Unknown	-	-	-	-	-	-	-	-	-	-	-	-	1	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Sampling in this program was considered effective with about 78% of the total population collected by poisoning. It is likely that population estimates are less reliable in areas of dense weed growth and poor water clarity, as determined in the 1979 experiment (Table 5b) by the numbers recaptured in the three sections examined.

Recovery of all fin-clipped stocked *S. fontinalis* whether of angling size or smaller was very low (0.38% in 1977, 0.15% in 1979). In July 1977, 4000 fish were released, of which a possible 82 were captured. If all these originated from this stocking, a recovery of 2% was achieved (between 0 and 7% recovery in portions of creek limited by barriers). However, none of the fish captured were fin-clipped and only six of the 82 caught were above 190 mm (Fig. 8a) or approaching 3+ year old as would be the case if they were from the 1977 stocking, suggesting a recovery of 0.15%. In addition 76 of the 82 caught in 1979 were fish between 27 - 68 mm total length, mostly in sections 13 and 14 (Fig. 8a, b). These fish must have resulted from a small breeding event in this section of the creek since they were far too small to be stocked fish. Since no identified males were caught in 1979 (Table 2), breeding must have occurred prior to the loss of males, in sections where eel numbers were low (Fig. 4).

Prior to the present study, it was not anticipated that eels would be present in the creek in large numbers and anglers thought that cormorants were the main predator of salmonids in the creek, and therefore responsible for the low angler returns. However, no evidence was found to support this angler perception of cormorants being the main cause of poor *S. fontinalis* survival, and no cormorants were seen fishing in the creek during the sampling programs. The results of these two surveys, however, show that the effectiveness of stocking with *S. fontinalis* is primarily influenced by *A. australis* predation, and secondarily influenced by the presence of barriers in the creek, and the presence of other large salmonids, particularly *S. trutta,* in the lower creek area.

Impact of *Anguilla australis* on salmonid populations in Wollondibby Creek

The impact of eels on *S. fontinalis* and the other salmonids was not suspected until after the first sampling of the creek on the 4 - 5 April 1977. In the 1977 sampling, when data on sections of stream where presence/absence of *A. australis* were separated (Table 9), *S. fontinalis* and *S. mykiss* was greater in density and biomass in *A. australis* free sections. *Salvelinus fontinalis* increased from 2.3 to 24.3 fish/ha and 0.358 to 0.911 kg /ha, and *O. mykiss* increased from 19.1 to 54.9 fish/ha and 1.48 to 2.36 kg/ha in *A. australis* free sections. The ratio of fish numbers in *A. australis* occupied and unoccupied areas is greater than the ratio of fish weights per hectare, (i.e. *S. fontinalis* 1:10.5 for fish numbers and 1:2.5 for fish weights, and *O. mykiss* 1:2.9 for fish numbers and 1:1.6 for weights), suggesting that *A. australis* has a greater effect on fish numbers than on fish weights. Thus, the greater pressures on smaller fish could be explained by predation.

This is supported by the length frequencies of *S. fontinalis* (Fig. 10) whereby only very few larger fish were found in *A. australis* occupied sections and numerous small fish were caught in *A. australis* free sections. In addition, in both sampling periods, when sections of the creek are ranked according to the numbers of *A. australis* present, there is an inverse relationship between sections with high *A. australis* numbers and numbers of both *S. fontinalis* and *O. mykiss* (Fig. 12, see also Figs 3,4).

These interactions are similar to those reported by O'Connor and Power (1973) who found that *Anguilla rostrata* had substantially reduced trout populations down to 7 fish/ha in a lake containing eels, compared with 48/ha in a lake not containing eels.

To obtain further evidence as to whether *A. australis* was predating on fish in Wollondibby Creek, eel stomachs were examined. This confirmed the existence of eel predation with 162 salmonids found in the stomachs of 42 (22.1%) of the eels out of the 190 eels caught in 1979 (Fig. 9a). Although a few of the fish taken by *A. australis* were moribund as a result of the poisoning and appeared fresh in the stomachs, most were partially or almost completely digested. It was assessed that fish killed by poisoning would be available for a maximum of 3 hours, and the state of digestion of the stomach contents indicated that most fish

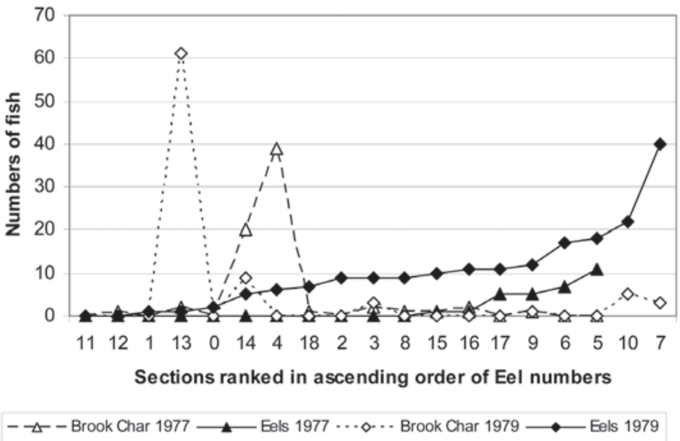

Figure 12. Sections of creek ranked in order of ascending numbers of eels for the 1977 and 1979 sampling plotted separately, showing the numbers of *S. fontinalis* in each of these sections.

Table 9. Comparison of numbers and Kg/ha of *O. mykiss* and *S. fontinalis* in areas where *A. australis* (Eels) are present and absent in 1977 sample.

	Area in hectares of sections	*O. mykiss*				*S. fontinalis*			
		No.	No. per hectare	Kg	Kg per hectare	No.	No. per hectare	Kg	Kg per hectare
Eels present	1.7283	33	19.09	2.560	1.481	4	2.31	0.619	0.358
Eels absent	2.7136	149	54.91	6.406	2.361	66	24.32	2.472	0.911

had been in the stomachs for much longer than 3 hours, and therefore had not been influenced by poison. Cairns (1942) indicated that large type food items could be identified in the eel diverticulum up to 36 hours after ingestion.

Fin damage was recorded on many of the larger salmonids caught. In *S. trutta* 4.8 % (2 of 42), in *O. mykiss* 25.8% (24 of 93) and in *S. fontinalis* 33.3% (2 of 6) of the large salmonids in 1979 had scars or damage (Table 6). Both the type of damage and the large amount of damage observed in non-spawning fish suggest that eels were contributing to the damage. Although fin damage in trout is known to occur during spawning, the various stages in healing and the fact that it was seen well outside the breeding season when virtually no large breeding adult salmonids were present, suggest that eels were the main cause. In addition, there were very few salmonids in the creek that were large enough to inflict the injuries seen.

The lack of scars on small salmonids below 130 mm (Table 6) suggests these fish are taken whole, as is confirmed by their presence in eel stomachs (Fig. 11). The mean estimated fish lengths recorded in eel stomachs was 58 mm (Fig. 11). If it takes 48 hours for digestion and evacuation of most of the fish remains in the stomach, then this population of eels may be capable of taking as many as 30,000 fish in a year out of the creek. The actual number is likely to be less than this, as feeding rate does slow down in winter and may even stop under very cold conditions (Cairns 1941; Burnet 1969b). However, predation of salmonids by eels is likely to be significant in Wollondibby Creek.

Other studies have shown eels to be important predators of salmonids too. *Anguilla dieffenbachia,* another anguillid in New Zealand, was shown to feed extensively on trout (Sloane 1984), and in New Brunswick (Canada) salmon streams, eels over 152 mm were important predators of young salmon (Godfrey 1957, cited in Scott and Crossman 1973). In most studies, eels above about 400 mm appear to be important fish predators. In this study only *A. australis* above 485 mm in length had salmonids in their stomach. However, nearly all eels caught were above 450mm in length, and in every section, the mean length of eels was above 500 mm (Fig. 9a, b).

In trout waters in New Zealand, Cairns (1950) found *A. a. schmidtii* between 400 mm and 750 mm in length contained no trout, but 30% of food in stomachs was other fish species. Mann and Blackburn (1991) concluded that piscivory was most marked in *A. anguilla* above 400 mm in length in English chalk streams, but effect on salmonids was small. Beumer (1979) found that *A. australis* fed mainly on teleosts and insects, while *A. reinhardtii* mainly teleosts in Macleods Morass in Victoria.

Since some studies demonstrate that eels generally over 400 mm have a limited effect and others a considerable effect on salmonids, it seems likely that the habitat characteristics of the creek, availability of food resources and the distribution of salmonids affect their vulnerability to eel predation. In Wollondibby Creek large numbers of small *S. fontinalis* stocked all together present a naïve population, of a suitable size for eel food. Coupled with the inverse relationship between eel numbers and numbers of *S. fontinalis* in various creek sections, it is likely that *A. australis* are exploiting this available prey in Wollondibby Creek, as salmonids form a significant part of the biomass of the creek, especially just after a stocking event. Thus it is likely that eel predation is a major factor in the low survival of *S. fontinalis* in Wollondibby Creek.

Impact of physical barriers on salmonid populations in Wollondibby Creek

The downstream waterfall in the lower portion of section 5 appeared to be a significant barrier to upstream movement of salmonids. The barrier consisted of large boulders and rock shelves creating an approximately 3m drop between up and down stream (see Appendix Photo 3 a). Since stocking of *S. trutta* ceased in NSW in 1967 and was not reintroduced until quite recently, most fish in the creek at the time of this study, were wild fish from Lake Jindabyne entering Wollondibby Creek for spawning. Only occasional large fish were capable of passing this barrier in peak flood periods. It is suspected that some of the fish above this waterfall found in the 1977 sampling (Fig. 3) were a remnant from pre- 1967 stocking that had bred in the creek.

It was confirmed that the downstream barrier was significant to the movement of *S. trutta* in the 1979 sampling, since all, or most fish, had been removed from the creek in the 1977 sampling, and re-population

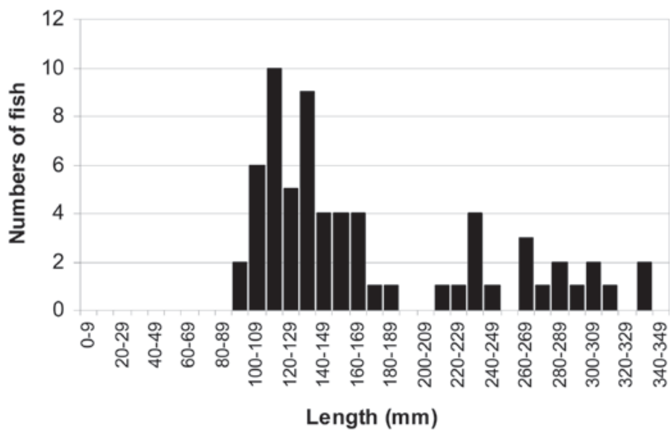

Figure 13. Length frequency of *O. mykiss* above first waterfall in Sections 5-17 in 1977, showing different size classes indicating breeding has occurred in the creek. Compare numbers with Fig. 6a.

had occurred (except for one fish) only below the lower barrier. The high numbers of small fish in the lower end of the creek reflect the influence on population densities of recruitment from successful breeding in this area. The fact that *S. trutta* of angling size dropped from 25 in 1977 to one in 1979 (Fig.5a), can be attributed to the 1977 poisoning, leaving no resident large adult fish in the creek. Large fish that had moved into the lower creek to spawn would have returned to Jindabyne Lake.

By contrast, *O. mykiss* are better jumpers than *S. trutta* and are able to pass some barriers during high river flows (Tilzey 1970). Although it is likely that the waterfalls present a barrier to movement for this species for much of the time,

O. mykiss were present in virtually all sections of creek, even in the 1979 sample when this species had been stocked below the waterfall in section 10. Since *O. mykiss* had been released into Wollondibby Creek for a number of years prior to 1977, at locations above and below the barriers in the creek, at least some of the fish sampled in 1977 are likely to have been from prior stockings. In some of the 70 or so fish upstream of the lower waterfall, the presence of several size classes, particularly those fish around 100 mm from sections 5-17 (Fig. 13), suggest this species has bred in the creek, since there had been no releases of fry into the creek since 1975. Most of those fish below the waterfall in section 5 (110 out of 182 in the creek) would have resulted from lake-run fish breeding in the creek.

After the 1977 sampling, 2000 fin clipped *O. mykiss* were stocked in the creek. Regeneration of fins over the 28 months since clipping and damage to fins caused by *A. australis* made identification of these stocked fish impossible. Only 20 *O. mykiss* based on expected size at recapture (3 year old fish) were likely to have originated from the stocked fish, suggesting a possible return rate of stocked fish of < 1.0%. However, *O. mykiss* can persist in the creek due to its ability to breed in the creek and traverse barriers to reach all sections.

Physical barriers within the creek may limit upstream movement of *S. fontinalis*, though it appears that downstream movement of this species occurred. In 1977, fish had been stocked in section 14 above the third barrier, but most were recovered in section 10 below it. In addition, fish that had bred in the stream had moved downstream in 1979. It is possible that *S. fontinalis* stocked in section 3 below the lower barrier in July 1977 may have moved into Lake Jindabyne but there is no evidence for any upstream movement of these fish over the lower barrier.

Distribution of S. *fontinalis* in the creek appeared to be patchy. Captures were clumped around section 9 and the lower part of section 10 in 1977 and were less than 110mm in length (Fig. 3, 8a, b). In 1979, fish around 65 mm in length were clumped in sections 13 and 14 (Fig.4, 8a, b). Only 11 of 70 caught in 1977 (15.7 %) and 12 of 82 caught in 1979 (14.6%) were outside these sections. This clumping seemed to be related to areas that were devoid of *S. trutta*, and had very low numbers of or no eels.

Since *S. fontinalis* were stocked above and below all physical barriers in the creek, it would appear that there was differential survival of them in these areas, and that there was little upstream movement of *S. fontinalis* across these barriers.

By contrast with salmonid movements, physical barriers present little resistance to movement of eels. As *A. australis* breeds at sea (Skrzynski 1974; Beumer 1996; Aoyama *et al* 1999: see also Castle 1963 with respect to the subspecies *Anguilla australis schmidtii)* and no stocking of eels has ever occurred in NSW in this system, it is assumed that the eels caught would have originated from the eastern seaboard and entered Lake Jindabyne via the Snowy River. Pease and Walford (2004) stated that *A. australis* occurred in higher proportion than *A. reinhardtii* at distances greater than 100 km upstream from the sea, as would be the case for Lake Jindabyne.

The problem of eel predation in the feeder streams of the Lake Jindabyne catchment should decline since impoundment. This can be inferred from the fact that male *A. australis* can spend 8-22 years at 38-55cm in length, and females 12 – 35 years at 56-93cm in length in freshwater, before migrating back to the sea to spawn (Todd 1974; Todd 1980; Beumer 1996). Pease *et al* (2004a) found *Anguilla reinhardtii* reached 575 mm in 10 years in coastal rivers. Since *A. australis* would grow slowly above the 500 mm length at which they were commonly caught (Burnet 1969a) and because of low temperatures at Jindabyne (Sloane 1984), it is suggested that *A. australis* caught in 1977 and 1979 could have been in Lake Jindabyne since prior to dam construction in 1967. However, it is possible that *A. australis* can climb Jindabyne Dam, since Woods (1964) reports on their superior climbing ability, they have been observed climbing vertical surfaces on nearby Tallowa Dam (*pers. obs*.), and some small eels between 228 and 350 mm in length were present in Wollondibby creek. It seems likely that most of the large eels caught would within the next few years return to sea to spawn. Eel numbers in Jindabyne would then decline due to the effect of the dam wall barrier which would limit migration into the lake. This is supported by the small numbers of smaller eels and essentially a single large size class present during the study.

Eels would be able to bypass the three barriers in Wollondibby Creek and colonize all sections of the creek. In 1977, 30 were collected and removed from the creek, representing most eels present, and in 1979, 190 were collected in the creek, most of which would have ascended the creek from Lake Jindabune following the poisoning in April 1977. The recolonisation of the creek by large eels from an apparently considerable stock of eels in Lake Jindabyne was rapid. This rapid movement into the creek is in contrast to the study by Burnet (1969b) on *A. a. schmidtii,* who found this species to be fairly sedentary except during its three migration stages; two upstream when up to 12 cm in length and the third when mature returning to sea at above 500 mm in length. Pease *et al* (2004 b) on the other hand came to the conclusion that anguillid eels in fluvial and tidal waters within this region generally have a restricted range but are capable of periodic extensive movements; possibly similar to what occurred in this study. Jellyman *et al*. (1996) showed that in *A. australis* tagged in a coastal lagoon (Lake Ellesmere) in New Zealand, 39% moved an average distance of 5 km. This distance moved would compare with an average distance of 8.9 km moved by eels in this study (maximum 17.6 km) assuming they have all moved upstream from Lake Jindabyne.

Interaction between salmonid species

In both 1977 and 1979 *S. trutta* were only found within creek sections 1 to 7 (Fig. 3, 4, 5b), mostly below the bottom barrier which was in section 5. Only one *S. fontinalis* was recovered in 1977 and 3 in 1979 (Fig. 8b) in these sections below the lower waterfall despite stocking in these areas prior to both sampling periods. In 1977, most *S. trutta* were below 150 mm in length, though the three largest *S. trutta* were 175, 217 and 310 mm in length. In 1979 there were 40 *S. trutta* present in the size range 160-240 mm and

one 331 mm in length (Fig. 5a). It is possible that the larger *S. trutta* predated on *S. fontinalis* in the lower sections of the creek, while smaller *S. trutta* could also have successfully competed with them for resources. Numbers of large *S. trutta* in this area of the creek would have been much greater during the spawning period and they would have returned to the lake shortly afterwards.

O. mykiss were present in virtually all sections of creek including those occupied by *S. fontinalis*. Above the second barrier where *S. trutta* were virtually absent, *S. fontinalis* survived albeit in low numbers but in some sections were more abundant than *O. mykiss* and in others less abundant. The ranges of sizes of both *O. mykiss* and *S. fontinalis* above the lower waterfall were very similar (Fig. 6a, 8a), and it is unlikely therefore that *O. mykiss* had a major adverse effect on survival of *S. fontinalis*. However, below the lower waterfall, large *O. mykiss* using the area for spawning could have competed with *S. fontinalis*. The low numbers of *S. fontinalis* found below the lower barrier could also be due to their movement out of the creek into Lake Jindabyne

Native species

Only a single large specimen of the other native fish *Galaxias olidus* (or *brevipinnis*) that naturally occur in the area was collected. Their virtual absence from this area fits with the findings of Tilzey (1976) that salmonids have caused loss of this galaxiid from areas where they have been introduced. A number of galaxiid communities have been found recently in the cool streams of the Dorrigo Plateau in the north eastern tablelands of NSW (Raadik 2005), which may be similarly under threat from salmonid introductions.

Conclusion

The data presented suggest that predation by *A. australis* is the main cause of the extremely low survival of *S. fontinalis* in Wollondibby Creek, and stocking of this species is unlikely to be successful in areas where eels have access to such streams or are prevalent in the area. This includes all streams which occur in the eastern coastal drainages. Predation would decrease and survival would be enhanced if fish were stocked at a larger size, preferably over 150 mm. Stocking should take account also of the location of stream barriers as they have a significant impact on movement and final distribution of fish, often causing clumping of numbers and possibly increasing the chance of predation. Before stocking salmonids into a stream, consideration should be given to the conservation of small native species, whose populations may be adversely affected by such stocking practices. It seems likely that numbers of *A. australis* present in the Lake Jindabyne watershed will decline because of the presence of the dam.

Acknowledgements

I wish to thank the New South Wales State Fisheries for support during this project. I should also like to thank John Malicki for field assistance during the sampling program and analysis of some of the data, and Ray Symons who was Manager, Gaden Hatchery, Jindabyne at the time, for general assistance and helping with the stocking and care of hatchery fish used in the study. I would also like to thank Samuel Crocker the current Manager of the Hatchery who has supplied me with much up to date information. I also wish to thank land holders in the area of the creek for providing access to carry out the sampling. Most importantly I would like to thank my partner Dr G. P. Courtice for her encouragement to complete this long overdue work and for her careful checking, editing and advice during revision and preparation of the manuscript.

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APPENDIX I

Photo 1. Wollondibby Creek.

APPENDIX I

Photo 2a. Salvelinus fontinalis.

2b. Salmo trutta.

2c. Oncorhynchus mykiss.

2d. Galaxias olidus.

Photo 3 a. Lower waterfall ((i) see Fig. 3,4), rock barrier about 3 m high, top and bottom of waterfall marked.

APPENDIX I

Photo 3b. Weir ((ii) see Fig. 3,4) approximately 1m high used for generating power.